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The effects of induced abortion on subsequent reproductive function and pregnancy outcome: Hawaii

Chin Sik Chung
and Patricia G. Steinhoff
in collaboration
with Roy G. Smith
and Ming-Pi Mi

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ABSTRACT This paper reports on an eight-year (1971–78) follow-up study of the effects of induced abortion on subsequent pregnancies and pregnancy outcomes among women in Hawaii. Follow-up was done by means of vital registration record-linkage of 16,961 women who had undergone induced abortions during the period 1970–74. The record-linkage identified 3,910 women who had one or more live births or spontaneous abortions after having had an induced abortion. These women were compared with a control group of 98,046 women having no known history of abortion. To complement data from vital registration records, clinical information was obtained from hospital records for 3,589 pairs of the abortion and control pregnancies matched on age and race of the women and on time of the event.

The pregnancy characteristics studied were short gestation, pregnancy complications, and labor complications. The pregnancy outcomes investigated were spontaneous fetal loss, ectopic pregnancy, low birth weight, congenital malformations, and infant death up to one year of age.

Comparisons revealed no difference between the abortion and nonabortion groups in overall rates of spontaneous fetal loss or in second-trimester fetal loss. The abortion group had a slightly higher rate of fetal loss than the control group in the first trimester of pregnancy. However, the increase in the early fetal loss rate can be explained by the competition between induced abortion and early fetal death. No significant association emerged between risk of spontaneous abortion and number of prior induced abortions.

The study found no overall relationship between history of induced abortion and subsequent ectopic pregnancy, but the incidence of ectopic pregnancy was five times greater among women who had had infection or retained secundines associated with prior induced abortion than among others in the abortion cohort. The risk of congenital malformations or postnatal death among subsequent live births was independent of a history of induced abortion.

Short gestation (< 37 weeks of gestation) was not affected significantly by prior induced abortion. Its incidence among nulliparous women with a history of single abortion was intermediate between that of the two control groups of nulliparous and parity 1 women. Rates of race-specific low birth weight were not significantly associated with a history of induced abortion. Nor was a significant association found between prior induced abortion and complications of pregnancy or labor. In general, women with a history of single abortion ranked between the nulliparous and parity 1 control groups in the incidence of such complications.

SUMMARY AND CONCLUSIONS

The present study was designed to study the effects of previous induced abortion on subsequent pregnancies and pregnancy outcomes. The pregnancy outcomes investigated were spontaneous fetal loss in each trimester, ectopic pregnancy, low birth weight, congenital malformations, and death of infants up to one year of age. The characteristics of subsequent pregnancies studied were short gestation, pregnancy complications, and labor complications.

The study was based largely on follow-up during 1971–78 of a cohort of women who had undergone induced abortion during the period of 1970–74 in Hawaii. The follow-up was carried out by means of record-linkage of the abortion cohort with birth and fetal death records filed at the State Department of Health. The record-linkage of 16,961 women in the abortion cohort identified 3,910 women who had one or more subsequent pregnancies that resulted in live birth or spontaneous fetal death. Selected for comparison with this group were women who had no known history of induced abortion as checked against the abortion cohort and the file of official induced abortion records. Altogether, 98,046 women formed the control group, which excluded repeat subsequent pregnancies of the same women. To complement the data from the vital registration records, we obtained additional clinical information on pregnancy and labor complications, congenital malformations, and women's reproductive history from hospital records for 3,589 pairs of the abortion and control groups matched for age, race, and time of the event.

An ancillary study was conducted on a sample of the entire data to investigate bias in the sampling of subsequent pregnancies, reliability of the vital records, completeness and validity of the record-linkage process, distribution of important confounding variables not reported in the vital records, and secondary infertility as a sequela of induced abortion. The study indicated that differential migration from Hawaii among women in the original abortion cohort tended to make those who remained more comparable to the control sample in their ethnic and age distributions. It also showed a high degree of completeness and validity of the record-linkage process. The vital records provided more complete information on a woman's experience of spontaneous abortion. An induced abortion was seldom reported as a spontaneous abortion. False negative history of induced abortion for the control women was estimated to be less than 5 percent. We found no significant differences between the abortion and control samples in their rates of smoking, alcohol consumption, and diabetes.

The vital data and the matched hospital data were analyzed separately. Using the Mantel-Haenszel χ^2 method, we analyzed the vital data stratified by maternal race, age, and parity (marital status in case of fetal loss). In the analysis of the stratified data, we classified parity in two ways: first, parity 0 versus parity 1 or more; and second, parity 0 for the abortion sample versus parity 1 for the control sample, and parity 1 or more for the abortion sample versus parity 2 for the control sample. The comparison of the nulliparous abortion sample with the uniparous control sample is of special significance because about half of all legal abortions in the United States are obtained by nulliparous women. The vital data were further analyzed by the multivariate logistic regression method. Next we examined the paired hospital data using McNemar's χ^2 test and multivariate logistic regression analysis. The hospital data were further tested for association of factors related to abortion procedure. The factors considered were age at first induced abortion, number of previous induced abortions, number of completed gestation weeks at last induced abortion, abortion procedure, use of laminaria, and abortion complications.

We examined subsequent fetal loss by trimester. Analysis of the vital data was somewhat hampered by the absence of information on reproductive history in fetal death records, although the hospital data corrected this deficiency. No significant association emerged between history of induced abortion and first-trimester fetal loss; the overall relative risk was 1.11. A theoretical consideration of competition between spontaneous abortion and induced abortion and different rates of unwanted pregnancies led to the conclusion that a small excess risk of early spontaneous abortion for the induced abortion sample is expected even in the complete absence of adverse effects of induced abortion. A slightly higher rate of first-trimester fetal loss was observed among subsequent pregnancies of women whose earlier pregnancy had been terminated by the suction procedure and sharp curettage or abortion procedure performed at less than nine weeks of gestation, than among women in the control group.

Prior induced abortion had no significant effect on second-trimester fetal loss during subsequent pregnancies, the estimated relative risk being 0.97. None of the abortion-related factors was found to be associated with the risk, although there was a nonsignificant increase in the risk with the D&C (dilation and curettage) procedure (relative risk = 1.59) There was a tendency for pregnancy outcomes of women with a history of induced abortion to be at lower risk of third-trimester fetal death than those of the control group, the statistical significance depending on whether or not parity effect was adjusted. Thus a slightly higher risk of first-trimester loss was compensated for by a lower risk for third-trimester fetal loss among women with a history of induced abortion. The relative risk was 1.01 for all types of fetal death.

We observed no significant association between induced abortion and ectopic pregnancy (relative risk = 1.26). Generally, there was no relationship between ectopic pregnancy and abortion procedure, use of laminaria, number of prior induced abortions, or length of gestation at the time of abortion. But there was a clear effect of the presence of postabortion infection or retained secundines on the risk of ectopic pregnancy, the incidence for pregnancies of women having a history of these complications being five times greater than for those without such complications.

Short gestation, defined as gestation length of less than 37 weeks, was not affected significantly by prior induced abortion, the estimated relative risk being 0.89. The apparently lower rate of short gestation among women in the abortion group was due to their having slightly greater gestation length (1.3 days) than the control group. Nulliparous women with a history of single induced abortion had a slightly lower rate of short gestation than the nulliparous control women, but they had a greater frequency of short gestation than the control women with parity 1. These findings suggest that the effect of induced abortion on gestation length of subsequent pregnancy is halfway between that of no previous pregnancy and that of a full-term pregnancy. Use of laminaria in prior induced abortion was associated with a lower rate of premature delivery than that of the control group.

We defined low birth weight using race-specific criteria: 2,500 grams for Caucasians and individuals of Hawaiian ancestry, 2,300 grams for non-Filipino Orientals, 2,200 grams for Filipinos, and 2,400 grams for other racial groups. Low birth weight unadjusted for gestation length showed a tendency similar to that observed in short gestation. When child's race and gestation length along with other covariates were allowed for in the logistic regression analysis, we could find no significant association between mother's history of induced abortion and low birth weight in subsequent pregnancies (relative risk = 0.92). The data also indicated that pregnancy outcomes of nulliparous women with a history of single induced abortion were intermediate between the groups of nulliparous and parity 1 control women. Multiple regression analysis of birth weight per se, with allowance for child's race, parity, and gestation length, revealed that the pregnancies of women in the abortion group resulted in a slightly but significantly greater average birth weight (38.3 grams) than those of the control group. This finding suggests that a prior pregnancy terminated artificially has some independent effect on birth weight of subsequent pregnancies but not as much as a full-term pregnancy.

No significant association could be detected between induced abortion and pregnancy complications in subsequent pregnancies, the relative risk being 1.10 with adjustment for covariates. However, the data indicate that a woman who has had an induced abortion is at higher risk of pregnancy complications in later pregnancy than a woman with one higher parity. But we found no difference between the abortion and control samples at the same parity levels. There was apparently more hyperemesis among women who had had induced abortions.

Labor complications followed a pattern similar to that of pregnancy complications. The overall relative risk was estimated to be 1.09. The data also suggested that a woman with a history of induced abortion has a higher risk of labor complications in subsequent pregnancies than if she had carried that earlier pregnancy to a full term.

The risk of congenital malformations was found to be independent of maternal history of induced abortion, the relative risk being 0.98 for the abortion group. Mortality of infants (under age one) born subsequently likewise showed no association with induced abortion of a prior pregnancy (relative risk of 0.99).

We conclude that in general there were few or no effects of prior induced abortion on subsequent pregnancies and pregnancy outcomes. Whatever minor effects demonstrated were found to be related to pregnancy order associated with induced abortion, not to induced abortion itself.

A general conclusion that can be drawn from the present study is that when induced abortion is carried out in a favorable medical setting, it will not increase the risk of any adverse consequences in subsequent pregnancies or pregnancy outcomes.

BACKGROUND AND AIMS OF STUDY

Induced abortion is considered to be the most commonly used surgical procedure (Sullivan et al., 1977) and accounts for about 30 percent of all pregnancies in the United States (Tietze, 1981). For a medical procedure practiced with such prevalence, it is imperative to know the long-term consequences. If there are risks of adverse effects of induced abortion on subsequent pregnancies or pregnancy outcomes, the risks must be precisely assessed.

Unfortunately, information on the subject is conflicting and clear agreement among published studies does not exist. Some of the observed international differences could be attributed to differences in the legal status of abortion, methods of abortion procedure, standards of health care, socioeconomic status of women seeking abortions, and demographic factors. In addition, differences in study design can account for inconsistent results between or within countries. Because of the recency of legalized induced abortion in the United States, data on its long-term effects are limited. Information available on the U.S. population up to this time also shows a disturbing inconsistency. The present analysis, which is based on a large prospective study, represents a further critical attempt to resolve the question concerning the risks of induced abortion.

Literature review

Inasmuch as long-term sequelae of induced abortion have received widespread attention in recent years, a large amount of literature has accumulated on the subject. We attempt no exhaustive review here but rather place emphasis on the critical consideration of major published studies. There are several general reviews on the subject of selected sequela variables (Tietze, 1981; Edstrom, 1975; Hogue, 1977; Cates, 1979; Grimes, 1979) that need not be duplicated here.

Late effects of induced abortion may be classified into the following categories: spontaneous fetal loss, ectopic pregnancy, low birth weight, short gestation, pregnancy complications, labor complications, congenital malformations, postnatal death, and secondary infertility. Available information on each of these conditions except secondary infertility is reviewed separately below. Since the requisites for studies of secondary infertility are distinct from those of studies of other sequela variables, that subject will be addressed in another report.

Spontaneous Abortion

Evidence is inconclusive concerning the relationship between induced abortion and spontaneous fetal loss at all stages of gestation (miscarriages and stillbirths), although available data are extensive.

Moriyama and Hirokawa (1966) found an increase in the rate of spontaneous abortion among women with a history of previous induced abortion in their retrospective study in Japan, which made no allowance for differences in maternal age or socioeconomic status between the case and control groups. Their study also showed that the rate of mid-trimester abortion was higher than that of first-trimester abortion, relative to the control group. The effect on mid-trimester fetal death was also noted by Wright et al. (1972), who reported a tenfold increase in the incidence of second-trimester abortion in pregnancies following induced abortion. Liu et al. (1972) questioned the magnitude of increased risk for mid-trimester abortion found by Wright et al., although they concurred on the presence of a significant relationship between the two factors. Pantelakis et al. (1973) found that 4.2 percent of pregnancies resulted in stillbirths among women admitting previous induced abortions, compared with 2.4 percent among women with no history of abortion in a study of patients in Athens. They noted no difference between the groups with induced abortion and with spontaneous abortion. Richardson and Dixon (1976), however, observed that the overall fetal loss among pregnant women having a history of vaginal termination was 17.5 percent, compared with 7.5 percent in a group of control patients who had had a spontaneous abortion earlier. In a similar comparison, Ratten and Beischer (1979) found a higher risk of mid-trimester spontaneous abortion for women with a history of induced abortion; they attributed one-half of this spontaneous loss to incompetent cervix. Other studies showing a positive association are by Dziewulska (1973) and Alberman et al. (1975).

On the other hand, studies showing no association between the two factors are equally numerous. Miltenyi (1964) found no increased risk of spontaneous abortion among women with a history of induced abortion in Hungary. Similarly, Roht and Aoyama (1973; 1974), in a study based on a mail survey and interviews, found no clear evidence of increased risk of either spontaneous abortion or stillbirth among women who had experienced induced abortion, although a more recent study by the same group of investigators claims an adverse effect of multiple induced abortions (Roht et al., 1976). Hogue (1975) found no association between induced abortion in first pregnancies with subsequent risk of spontaneous abortion or stillbirth in Yugoslavian women. Daling and Emanuel (1975; 1977) failed to detect any association between history of induced abortion and fetal loss in subsequent pregnancies under two diverse environments, Taiwan and the United States, using the matched-pair cohort design. Although Harlap and Davies (1975) demonstrated adverse effects of prior induced abortion on many aspects of subsequent pregnancies, they found no such effect on stillbirths. In an age-matched retrospective study in New York City, Kline et al. (1978) found no significant association between history of induced abortion and subsequent spontaneous fetal loss.

Recently, Harlap et al. (1979) reported a greater incidence of mid-trimester spontaneous abortion among nulliparous women with prior induced abortion than among the control women in the San Francisco area. They pointed out that the higher rate was largely among women who had had an abortion procedure in the early years of legalized abortion. Levin et al. (1980) reported a twofold to threefold increase in the risk of first-trimester spontaneous abortion and loss up to 28 weeks of gestation only for women who had had two or more prior induced abortions.

An international study coordinated by the World Health Organization (WHO, 1979) is highly revealing, pointing to underlying problems associated with the conflicting observations among regions and populations of the world. The study covered eight cities in Europe and grouped them into three clusters for analysis based on similarity of medical practice. Among the three clusters of cities, there was a significant association between history of induced abortion and mid-trimester spontaneous abortion in only one city cluster (East European cities), where dilation and curettage (D&C) was practically the only abortion procedure used. The study also showed that increases in the risk of mid-trimester abortion are similar in pregnancies preceded by D&C abortion or spontaneous abortion, in contrast to pregnancies preceded by a live birth.

In a summary of the results of seven major worldwide studies on mid-trimester spontaneous abortion, Tietze (1981) found that estimated relative risks varied widely, 0.71 to 3.13, with a limited number showing statistical significance, although some data were shown to lack the power of detecting a doubled risk.

Ectopic Pregnancy

Most of the observations of positive association between history of induced abortion and ectopic pregnancy have been in East European countries. Kotasek (1971) found an increase of ectopic pregnancy among women with previous induced abortion in Czechoslovakia. Beric and Kupresanin (1971) noted a secular trend of reduced ectopic pregnancy with widespread use of vacuum aspiration for induced abortion in the 1960–70 period in Yugoslavia, whereas Masic (1972) found a positive association between the frequencies of illegal abortion and subsequent ectopic pregnancy. No direct relationship could be established between the two factors, however, in a case-control study in Ljubljana, Yugoslavia, by Hren et al. (1974). In a study in Greece where elective abortion is illegal but practiced commonly, Panayotou et al. (1972) concluded that aborters had a tenfold greater risk of ectopic pregnancy than nonaborters.

Data originating in Japan show a negative association. Even though a study by Shinagawa and Nagayama (1969) of a small sample of clinical cases of ectopic pregnancy found a high percentage (68 percent) of women who had a history of induced abortion, a case-controlled study by Sawazaki and Tanaka (1966) of a large sample found no definite association between the two factors. Their findings were supported by another Japanese study (Roht and Aoyama, 1973). A limited amount of information is available on the U.S. population. A study of women in the Seattle area is inconclusive because of the small number of observations involved (Daling and Emanuel, 1977).

Low Birth Weight and Short Gestation

Low birth weight and short gestation are discussed together because of their close relationship. The term "prematurity" has been commonly used in the literature to denote underdevelopment of the newborn, as measured by birth weight. The birth weight of 2,500 grams is used as the criterion for prematurity in Caucasian populations. But prematurity as so defined yields no information as to whether the underdevelopment of a baby is due to a shorter than normal gestation period or to factors unrelated to gestation length.

Moriyama and Hirokawa (1966) reported that of women admitted to a Tokyo hospital for premature delivery (28–36 weeks of gestation), 32 percent had had a prior induced abortion, compared with 21 percent of the control group admitted for full-term delivery. Also in Japan, Roht and Aoyama (1973; 1974) found no significant difference in the incidence of low birth-weight babies between their abortion cohort and the control group. But they reversed that conclusion in a subsequent analysis (1976).

Data from Eastern European countries tend to show positive associations between history of induced abortion and low birth weight or short gestation. Dolezal et al. (1970) reported a significantly higher incidence of prior abortion among 189 women who experienced short gestation than among 197 controls. Similar results were reported by Miltenyi (1964) and Atanasov et al. (1972). Czeizel et al. (1970) raised the possibility that an increased number of low birth-weight infants may have been due to a high rate of induced abortions in Hungary.

Pantelakis et al. (1973) reported that the rate of premature delivery among women with a history of induced abortion was about double that of a control group in Greece. This finding was supported by Papaevangelou et al. (1973), who found a similar association between short gestation and prior spontaneous abortion. But the latter group of investigators concluded that there was no adverse effect of previous induced abortion on birth weight independently of premature delivery. Harlap and Davies (1975) reported a 34 percent greater incidence of low birth weight among women with a history of induced abortions than in a control group.

More recent studies in which confounding variables are better controlled show no association of induced abortion with low birth weight or short gestation. Hogue (1975) detected no significant difference in the frequency of low birth weight among abortion and nonabortion Yugoslavian women, as did Obel (1979a) with a Danish population. Daling and Emanuel found no effect of previous abortion on either length of gestation or the rate of low birth weight among women in Taiwan (1975) or the United States (1977). Similar findings were reported from Boston by Schoenbaum et al. (1980). The 1979 WHO study showed significantly greater frequency of short gestation among mothers who had terminated the first pregnancy by vacuum aspiration than among mothers who had had only a prior live birth (5.7 versus 2.0 percent). On the other hand, Obel (1979b) observed that among women with a history of induced abortion a higher risk of low birth weight was associated with cervical canal dilatation greater than 12mm. and with recurettage.

Summarizing a number of major studies, Tietze (1981) concluded that the average relative risks for abortion groups were 1.08 and 1.05 for low birth weight and short gestation, respectively. He further noted that the relative risks were higher when the study groups with only a single induced abortion were compared with the controls of parity 1.

Congenital Malformations

Data are limited on congenital malformations in subsequent pregnancies as a sequela of induced abortion. Daling and Emanuel found no greater risk of congenital malformations in babies born subsequent to induced abortion than in the control group either in Taiwan (1975) or in the United States (1977). But Harlap and Davies (1975) reported a higher incidence of both major and minor congenital malformations among an abortion cohort in Israel.

Polednak and Oski (1976) observed a secular parallelism between the general incidence of oral clefts and legalization of induced abortion in upstate New York, but could establish no causal relationship. Two recent studies on U.S. populations (Schoenbaum et al., 1980; Bracken and Holford, 1979) demonstrated no association between prior induced abortion and risk of congenital malformations in subsequent pregnancies.

Postnatal Death

Findings on postnatal death rates as a function of previous abortion history are equally confusing. In an Israeli sample, substantially higher than normal rates of early and late neonatal death were observed among infants of mothers with a history of induced abortion (Harlap and Davies, 1975). The results were negative in studies in Taiwan (Daling and Emanuel, 1975) and the United States (Daling and Emanuel, 1977; Schoenbaum et al., 1980).

Pregnancy Complications

As with congenital malformations, data are limited on complications of pregnancy as a sequela of previous induced abortion. In their prospective study of Israeli women, Harlap and Davies (1975) found a greater occurrence of bleeding during the first trimester among the abortion group than among the controls, but no difference in blood-group isoimmunization, toxemia, and hydramnios. Dziewulska (1973) and Atanasov et al. (1972) also reported more bleeding during subsequent pregnancies of women with a history of induced abortion. Among several factors studied, Obel (1979a) found a higher incidence of bleeding before 28 weeks of gestation for previous aborters than for control women.

In contrast, Furusawa and Koya (1966) found no association between previous induced abortion and pregnancy complications. Schoenbaum et al. (1980) observed that women of second gravidity who had had a single induced abortion resembled nulliparous control women in their rates of first-trimester bleeding and toxemia of pregnancy.

Labor and Delivery Complications

Studies report conflicting results on labor and delivery complications. Furusawa and Koya (1966) found no significant difference between controls and previous aborters in their rates of instrumental delivery, amount of bleeding, or length of third stage of labor; although the authors suggested a possibility of moderately longer first and second stages of labor for the aborter group. Czeizel and Bognar (1971) suggested a possible relationship between a rising incidence of induced abortions and delivery complications due to placenta previa or premature detachment of placenta. On the contrary, Atanasov et al. (1972) reported fewer delivery complications among women with a history of induced abortion.

Other investigators claim to have found more definite adverse effects of induced abortion on labor and delivery. Clow and Crompton (1973) pointed out a substantial increase for previous aborters in the risk of uterine rupture during subsequent pregnancy among women with a history of hysterotomy. Slunsky (1964) observed among abortion women a higher incidence of premature labor and slightly greater frequency of operative intervention or excessive hemorrhage than in the control group. Dziewulska (1973) noted that prolongation of the third stage of labor was more common for women who had previous induced abortion than for his control group, a finding that appears to be supported by data from Israel (Harlap and Davies, 1975).

However, more recent studies by Obel (1979a) and Schoenbaum et al. (1980), with better control of confounding factors, showed no definitive association between induced abortion and selected delivery-complication variables.

In a follow-up study in California, Madore et al. (1981) examined various sequela variables together, including spontaneous abortion, ectopic pregnancy, neonatal death, low birth weight, and congenital malformations. Adverse outcome as defined by all of these factors was slightly greater among women with a history of induced abortion, but the relative risk was barely significant (1.45).

Aims of this study

From the preceding discussion, it is clear that in no specific area could we find agreement or consistency among different investigators on the effects of induced abortion on subsequent pregnancies. It is difficult to assess the extent to which the observed inconsistencies among studies are a reflection of true differences, faulty study design, or incomplete control of confounding variables. Even under the best conditions of study design and data analysis, some inconsistency in results may be expected, for confounding social, demographic, and health-care conditions are known to vary among different regions and countries, as illustrated by the 1979 WHO study. Given the methodological difficulties, well summarized by Hogue (1979), it seems unproductive to generalize from studies carried out under different conditions. The value of a well-designed study with good control of confounding factors under a specific condition cannot be overemphasized.

The present study attempts to clarify the issue by using a prospective study design to analyze the relative risks of induced abortion among a large sample of women in Hawaii. The association between induced abortion and complications of later pregnancy and birth is examined. Also evaluated are the possible risks of induced abortion in relation to variables associated with the abortion itself, including procedure used, number of abortions, abortion complications, gestation stage at induced abortion, and age at first induced abortion.

STUDY PLAN AND MATERIALS

General design of the study

In general, the present study followed a historical prospective design. A cohort of women (abortion cohort) who had documented records of induced abortions performed during the period of 1970–74 were followed up for subsequent pregnancies through the vital registration system of the Hawaii State Department of Health. The follow-up period was 1970 through 1978. Attributes of pregnancies and their outcomes were compared with those of the control women, who had no known history of induced abortion. The characteristics of pregnancy and pregnancy outcome under study were pregnancy complications, labor and delivery complications, fetal death (spontaneous abortion and stillbirth), ectopic pregnancy, short gestation, low birth weight, congenital malformations, and postnatal death to one year of age.

Two types of controls were used for comparison. The first control consisted of all pregnancies reported as live births or fetal deaths among women who had no known history of induced abortion (referred to as "elective abortion" by the Health Department). Repeat pregnancies of the same women were excluded from analysis for both the abortion and the control groups. The second control was a subset of the preceding control pregnancies that were matched against the pregnancies of women with histories of induced abortion on the basis of race, maternal age, and time of occurrence of the subsequent event (birth or spontaneous abortion).

Abortion cohort

The State of Hawaii is one of the first states to legalize induced abortion. The law, which became effective in March 1970, originally had the provisions that: (1) the abortion procedure be performed prior to the stage of extrauterine viability of the fetus, (2) the procedure be carried out in an accredited hospital, and (3) the women treated be resident in the state for a minimum of 90 days immediately before the date of abortion. The latter two provisions were declared invalid in October 1974 by the State Attorney General after the 1973 U.S. Supreme Court decisions on the subject.

The Hawaii Pregnancy, Birth Control, and Abortion Study (HPBCA) was initiated to assess effects of the new state law on the use of induced abortion for birth control and to investigate personal decision-making processes (Smith et al., 1971; Steinhoff et al., 1972; Diamond et al., 1973; Steinhoff et al., 1975; Smith et al., 1976; Smith et al., 1978). The study included all cases of induced abortions from March 1970 through June 1974 that were performed in all Hawaii hospitals except for a few small remote hospitals. Medical and demographic information was obtained from hospital records on each case by personnel assigned by the project. The cohort consisted of 16,961 women who had had a total of 18,786 induced abortions. In addition, social and attitudinal information was collected on an 85 percent sample of the cases. The distribution of the 18,786 abortions by month and year of occurrence is given in Table 1. Of these abortions, there was no identifying information on 255 cases that could not be followed up for the present investigation. Thus 18,531 previous abortions of 16,719 women whose subsequent pregnancies could be followed up are the subject of the present study.

The original study provided for the present study the following critical information on each induced abortion of the abortion cohort: date of abortion, estimated maximum gestation time, abortion procedure used, use of laminaria and oxytocin, and complications associated with the procedure. In addition the study collected reproductive histories of the women and other pertinent information. These will be discussed in detail in another section.

TABLE 1 Number of abortions of cohort women, by month and year of abortion

Month	1970	1971	1972	1973	1974	All
January		332	389	416	416	1,553
February		301	360	389	370	1,420
March	222	353	448	433	396	1,852
April	293	376	403	377	362	1,811
May	292	344	428	404	375	1,843
June	300	355	370	394	353	1,772
July	351	386	376	387		1,500
August	298	386	416	433		1,533
September	315	385	388	346		1,434
October	306	371	364	371		1,412
November	264	317	351	346		1,278
December	317	367	337	357		1,378
Total	2,958	4,273	4,630	4,653	2,272	18,786

Record-linkage

Initially, the records of the induced-abortion cohort were linked with those of fetal death certificates filed at the State Health Department. By law, all fetal deaths, including spontaneous abortions and induced abortions, are reportable to the Health Department in Hawaii. Subsequently, the abortion cohort data were also linked with the file of birth certificates because it was found that a few induced abortions were reported as live births immediately followed by postnatal death.

There were several reasons for this initial step. First, we wished to test the yield and reliability of the record-linkage process with the clearly documented basic data of the abortion cohort. Second, some information on the cohort women from the vital registry records could be used in comparison with the control group. Third, we were interested in knowing the degree of completeness and accuracy to which induced abortions were reported to the Health Department. And fourth, we wanted to explore the possibility of an induced abortion being misreported as a spontaneous abortion in the official file.

The details of that study and its findings are reported elsewhere (Chung et al., 1979; Chung et al., 1981). Therefore, only a brief summary is presented here. The data used in linking the two files to the same event were: first name, maiden name, age and race of the woman, and date and place (hospital code used) of the event. When an absence or ambiguity of maiden name existed, the other last name was also used for the linking purpose. A match was declared when there was no discrepancy in these items of information between the two sets of records. Occasional questions on race occurred with persons of mixed ancestry, particularly when a woman was part-Hawaiian. A woman with mixed Hawaiian background might call herself a part-Hawaiian, or she might list some or all of her ancestral background. For cases like this, the match was considered complete as long as the Hawaiian component was stated in both files, provided no discrepancy was present in other items of information. For these cases, individual judgment had to be made.

Table 2 shows the result of matching all identified cohort abortions with the records of fetal death and birth files by year. The rate of match is indeed high, 96.1 percent over all the years. There was gradual improvement each year until 1974, when the abortion procedure was allowed to take place in clinics for the first time. Our estimate of matching rate is conservative because our criteria of match were

TABLE 2 Matches of identified induced abortions with records of fetal death and live birth, by year

Year	Total in abortion file	Matches with fetal death	Matches with live birth	Not matched	Proportion of matches
1970	2,870	2,728	2	140	0.951
1971	4,191	4,083	1	107	0.974
1972	4,591	4,488	0	103	0.978
1973	4,632	4,471	2	159	0.966
1974	2,247	2,025	0	222	0.901
Total	18,531	17,795	5	731	0.961

stringent. Taking account of other factors, however, we estimated that the rate of reporting induced abortions performed in hospitals to the State Health Department was 97.4 percent, with a maximum estimate of 98.8 percent (Chung et al., 1979).

Table 3 classifies 17,800 linked cohort cases by year of occurrence, type of abortion (elective or therapeutic), and source of information. The vital registry system recorded 98.75 percent of the cohort abortions as elective or therapeutic. Within the category of elective induced abortion as reported by hospitals, 98.72 percent were also reported as such in the vital registration. The "other" group as classified by the vital registration includes five cases that were reported as live births, although all of these were also registered as postnatal deaths occurring on the same date. Twenty-nine cases of induced abortion in the abortion cohort were classified as spontaneous abortion or miscarriage in the vital registry data. The rate of this type of misclassification was 1.7 per 1,000, which is negligible for all practical purposes. Nearly all of the "other" category were unspecified or unknown for cause of fetal death. The small observed rate of misclassification of induced abortion as spontaneous abortion in the vital registration records indicates a high degree of reliability of the vital data as a source of study for spontaneous abortion distinguished from induced abortion.

Subsequent pregnancy outcomes of the cohort women were searched by using essentially the same linking process as above, although the information on date of the event and hospital were not useful except for special cases. Table 4 shows the distributions of the cohort women by race and age at the time of first observed induced

TABLE 3 Elective and therapeutic abortions, by source of data

Year and classification in abortion file	Total	Classification in vital records		
		Elective	Therapeutic	Other
1970				
Elective	2,676	2,601	4	71
Therapeutic	54	27	22	5
1971				
Elective	4,029	3,956	3	70
Therapeutic	55	31	16	8
1972				
Elective	4,430	4,396	6	28
Therapeutic	58	35	18	5
1973				
Elective	4,420	4,389	5	26
Therapeutic	53	42	11	0
1974				
Elective	1,995	1,984	1	10
Therapeutic	30	24	6	0
All years				
Elective	17,550	17,326	19	205
Therapeutic	250	159	73	18

abortion and of a subset of these women who had at least one reported subsequent pregnancy resulting in a live birth or spontaneous fetal death during the period 1971–78. Because of only one observed subsequent pregnancy in 1970, that year is excluded from further consideration. Table 4 also shows the distribution of reported births and spontaneous fetal deaths for 1975 (Hawaii Department of Health, 1975) for comparative purposes. The race of women was classified into five categories: Caucasian, Hawaiian or part-Hawaiian, Filipino, Oriental, and Other. Hawaiian and part-Hawaiian were pooled because of their general similarity in cultural and socioeconomic background and the difficulty of specifying racial components for part-Hawaiians. Japanese, Chinese, and Koreans were combined to form the Oriental group since these groups have similar cultural and socioeconomic characteristics and there were relatively fewer Chinese and Koreans in

TABLE 4 Distributions of cohort women, cohort women having at least one subsequent live birth or spontaneous fetal death, and general population in 1975, by race and age at initial induced abortion

Race and age group	All cohort women (1970–74)		Cohort women with subsequent pregnancy (1971–78		General population (1975)	
	Number	Prop.	Number	Prop.	Number	Prop.
Caucasian						
< 20	1,511	.0945	355	.0908	742	.0431
20–24	2,571	.1608	474	.1212	2,301	.1337
25–29	1,232	.0771	182	.0465	1,857	.1079
> 29	1,083	.0677	77	.0197	979	.0569
All age groups	6,397	.4001	1,088	.2783	5,879	.3416
Hawaiian and part-Hawaiian						
< 20	657	.0411	369	.0944	856	.0497
20–24	677	.0423	326	.0834	1,364	.0793
25–29	370	.0231	110	.0281	856	.0497
> 29	406	.0254	45	.0115	492	.0286
All age groups	2,110	.1319	850	.2174	3,568	.2073
Filipino						
< 20	376	.0235	191	.0488	399	.0232
20–24	516	.0323	233	.0596	994	.0578
25–29	353	.0221	128	.0327	894	.0519
> 29	483	.0302	58	.0148	781	.0454
All age groups	1,728	.1081	610	.1560	3,068	.1783
Oriental						
< 20	1,171	.0732	351	.0898	219	.0127
20–24	1,647	.1030	533	.1363	699	.0406
25–29	842	.0527	202	.0517	1,401	.0814
> 29	1,303	.0815	86	.0220	1,042	.0605
All age groups	4,963	.3104	1,172	.2997	3,361	.1953
Other						
< 20	176	.0110	60	.0153	203	.0118
20–24	312	.0195	85	.0217	564	.0328
25–29	167	.0104	37	.0095	372	.0216
> 29	136	.0085	8	.0020	194	.0113
All age groups	791	.0494	190	.0486	1,333	.0775
Total	15,989	1.0000	3,910	1.0000	17,209	1.0000

the sample. The "Other" category consisted of heterogeneous groups including other unmixed ethnic groups and interracial crosses other than part-Hawaiians. Individuals of unknown racial origin or age are not included in the table.

The table includes only those cohort women whose induced abortions were reported to the State Health Department, as evidenced by record-linkage and by valid information on race and age at the time of the recorded induced abortion. Among the 15,989 initial cohort women, 3,910 were reported to have had subsequent pregnancies. It is clear that the cohort women who became pregnant subsequently and had a live birth or spontaneous fetal loss were not a random sample of the original cohort. Among these women, there were fewer Caucasians and, as expected, more young women. The decrease of Caucasian women among those having repeat pregnancies can be partly explained by the fact that a large number of these women were the spouses of military personnel having limited tours of duty in Hawaii and therefore the women were lost to follow-up. The racial distribution of women who had subsequent pregnancy outcomes of live birth or spontaneous fetal loss better approximates the distribution of the general population of Hawaii as seen in Table 4. There was a somewhat higher frequency of Oriental women among the women who later became pregnant again than among the general population of 1975.

Table 5 shows reported first subsequent pregnancies of the abortion cohort women by type of pregnancy outcome, race, and age at initial induced abortion. The overall frequency of fetal death among these pregnancies was 9.59 percent, which includes all types of spontaneous fetal deaths except for induced abortions. Overall, 24.5 percent of the cohort women had one or more ascertained subsequent pregnancies that resulted in delivery or spontaneous abortion during the period, the lowest proportion being 17.0 percent for Caucasians and the highest 40.3 percent for Hawaiians and part-Hawaiians. Of the 3,910 women in this group, 1,533 or 39.2 percent had repeated subsequent pregnancies reported as delivery or spontaneous abortion (Table 6).

Controls

Two types of controls were formed for the purpose of comparison with pregnancies of the abortion cohort women. The first control group was derived from all registered births and spontaneous abortions of women who had no known record of induced abortion during the

TABLE 5 Distribution of cohort women having subsequent pregnancy, by race, age at first induced abortion, and outcome type, and proportion of cohort women having reported subsequent pregnancy

Race and age group	Live births	Fetal deaths	Total	Total number in cohort	Prop. of cohort women with subsequent pregnancy
Caucasian					
< 20	321	34	355	1,511	.2349
20–24	428	46	474	2,571	.1844
25–29	157	25	182	1,232	.1477
> 29	57	20	77	1,083	.0711
All age groups	963	125	1,088	6,397	.1701
Hawaiian and part-Hawaiian					
< 20	346	23	369	657	.5616
20–24	296	30	326	677	.4815
25–29	98	12	110	370	.2973
> 29	40	5	45	406	.1108
All age groups	780	70	850	2,110	.4028
Filipino					
< 20	184	7	191	376	.5080
20–24	222	11	233	516	.4516
25–29	114	14	128	353	.3626
> 29	47	11	58	483	.1201
All age groups	567	43	610	1,728	.3530
Oriental					
< 20	320	31	351	1,171	.2997
20–24	493	40	533	1,647	.3236
25–29	183	19	202	842	.2399
> 29	67	19	86	1,303	.0660
All age groups	1,063	109	1,172	4,963	.2361
Other					
< 20	54	6	60	176	.3409
20–24	67	18	85	312	.2724
25–29	34	3	37	167	.2216
> 29	7	1	8	136	.0588
All age groups	162	28	190	791	.2402
Total	3,535	375	3,910	15,989	.2445

TABLE 6 Distribution of cohort women having subsequent pregnancy, by number of subsequent pregnancies, race, and age at first induced abortion

Race and age group	Only one subsequent pregnancy	Two or more subsequent pregnancies	Total
Caucasian			
< 20	211	144	355
20–24	309	165	474
25–29	127	55	182
> 29	59	18	77
All age groups	706	382	1,088
Hawaiian and part-Hawaiian			
< 20	172	197	369
20–24	177	149	326
25–29	66	44	110
> 29	34	11	45
All age groups	449	401	850
Filipino			
< 20	96	95	191
20–24	135	98	233
25–29	97	31	128
> 29	46	12	58
All age groups	374	236	610
Oriental			
< 20	198	153	351
20–24	351	182	533
25–29	145	57	202
> 29	70	16	86
All age groups	764	408	1,172
Other			
< 20	21	39	60
20–24	36	49	85
25–29	20	17	37
> 29	7	1	8
All age groups	84	106	190
Total	2,377	1,533	3,910

period 1971–78. For this period, all live births and spontaneous fetal deaths minus pregnancy outcomes linked with the abortion cohort women were further linked with the file of induced abortions obtained from the vital registration system. If a live birth or spontaneous fetal death was preceded by an induced abortion for the same woman, the outcome was eliminated from this general control group. In order to detect repeat pregnancies among the remainder, all records were linked with one another on the basis of names of infants' parents (family name and initials of first and middle names), and their birth year. Parental races and pregnancy order were further used for checking the consistency of linked records. This phase of linkage was done in the laboratory of Dr. Ming-Pi Mi as part of his ongoing research project. The elimination of these repeated pregnancies left 98,046 deliveries or spontaneous abortions during the period 1971–78 for the control. Table 7 shows the distribution of the sample by maternal race and age at the time of the outcome event. The control formed in this manner has the risk of inducing "false negative" cases in whom the induced abortion experience of the pre-1970 period is not recognized. The degree of possible contamination and its effects on the results of analysis will be discussed in later sections.

The control sample described above suffers from a certain weakness, although the size of the sample is sufficiently large to make up for some deficiencies. The vital registration data are incomplete for the reproductive history of many women who had spontaneous abortions, and reports on complications of pregnancy or delivery and congenital malformations could be incomplete or nonspecific. To correct for these problems, we formed the second control group by matching with the abortion cohort subsequent pregnancies reported during the period 1970–76. The matching was done on the basis of maternal racial group, maternal age at the time of subsequent event, and time of occurrence of the event. For the matching purpose, race was classified into the five groups described earlier, whereas age was in years. For time of occurrence, a control was considered to be matched with the cohort case when the control event took place within the same month or within one month before or after the cohort event. Parity or pregnancy order was not one of the matching criteria because, unfortunately, no such information was recorded by the vital registration system for spontaneous abortions occurring before 16 weeks of gestation; for such cases an abridged or "short" form was employed. Ex-

TABLE 7 Control pregnancy outcomes, by race and age

Race and age group	Total number of outcomes	Number of outcomes excluding repeated pregnancies
Caucasian		
<20	5,504	5,194
20–24	17,965	15,302
25–29	14,447	11,320
>29	8,156	6,032
All age groups	46,072	37,848
Hawaiian and part-Hawaiian		
<20	6,244	5,556
20–24	10,215	6,514
25–29	6,608	3,615
>29	4,109	2,554
All age groups	27,176	18,239
Filipino		
<20	3,114	2,782
20–24	7,024	4,877
25–29	6,705	4,227
>29	5,903	3,755
All age groups	22,746	15,641
Oriental		
<20	1,601	1,517
20–24	5,440	4,278
25–29	10,897	7,504
>29	8,393	5,333
All age groups	26,331	18,632
Other		
<20	1,530	1,398
20–24	3,990	3,165
25–29	2,625	1,911
>29	1,599	1,212
All age groups	9,744	7,686
Total	132,069	98,046

cluded from the cohort of subsequent pregnancies were multiple births, outcomes with no hospital code, and outcomes that took place in a hospital different from the hospitals used for earlier induced abortions.

For all of the matched cohort and control pregnancies, hospital maternity records were searched to obtain additional information on reproductive history of the woman, pregnancy complications, labor and delivery complications, congenital malformations, and postpartum complications. The information on congenital malformations was less complete for babies delivered at Tripler Army Medical Center, where infant records were filed separately from the maternity records, than at the other hospitals.

The matching process produced a total of 3,589 pairs of observations for the abortion and control groups. However, detailed reviews of hospital records revealed a small number of incorrect entries for events reported to the State Health Department as spontaneous fetal deaths. These included 12 suspected pregnancies that proved to be false (eight in the abortion group and four in the control group), six cases of septic abortions equally distributed between the two groups, and 18 cases of induced abortions (13 in the abortion group and five in the control group). All of the pairs with these types of discrepancies were excluded from pairwise comparisons. Excluded also were pairs of observations in which an IUD *in situ* was detected at the time of delivery, or there was a documented history of induced abortion (79 cases) according to hospital and Health Department abortion records. When these exclusions were made, 3,416 pairs of observations remained for matched comparison. All valid data were used, however, when analysis was confined to the abortion cohort. Table 8 shows the number of pairs by race and maternal age.

The observations on the control sample yielded some information about the magnitude of the presence of "false positive" individuals in the group in the main study. With 3,589 subjects as the base, the 79 cases having a documented history of induced abortion represented only 2.20 percent of the sample. This degree of contamination of the control sample is not likely to affect the results of the main study significantly. We will discuss this issue further in the section on the ancillary study.

ANCILLARY STUDY

Purpose of the ancillary study

The main study design described above assumes that: (1) the women followed up and ascertained to have had subsequent pregnancies were

TABLE 8 Number of paired observations, by race and maternal age

Race and age group	Number of pairs
Caucasian	
< 20	111
20–24	326
25–29	262
> 29	137
All age groups	836
Hawaiian and part-Hawaiian	
< 20	182
20–24	405
25–29	206
> 29	85
All age groups	878
Filipino	
< 20	73
20–24	210
25–29	167
> 29	99
All age groups	549
Oriental	
< 20	96
20–24	358
25–29	327
> 29	156
All age groups	937
Other	
< 20	31
20–24	94
25–29	67
> 29	24
All age groups	216

a representative sample of the abortion cohort, (2) the data obtained from record-linkage portray real events with completeness and accuracy, (3) the control subjects had no positive history of induced abortion, and (4) such possible confounding variables as diseases, smoking of cigarettes, and use of alcohol or drugs are evenly distributed between the abortion and control groups. The main study design, however, did not enable us to address the important question of effects of induced abortion on secondary infertility. (That subject will be the topic of another report.) In order to explore this question, an ancillary study was designed.

Design of the ancillary study

A sample of 1,200 elective abortion subjects and 1,200 control subjects who had subsequent births or spontaneous abortions was drawn from the pool of 1970–74 vital statistics records. The sample was distributed across the four years so that case loss over time could be studied. To maximize the availability of background data, we further restricted the sample to two periods of a month each in each year during which the abortion recipients and live-birth controls had been studied extensively earlier (Steinhoff et al., 1975; Diamond et al., 1973; Steinhoff et al., 1979). The eight subsamples were stratified by age and ethnicity to correspond to the population base from which they were drawn. A supplementary sample was also drawn of women with induced abortion histories who had already been record-linked to a subsequent birth or spontaneous abortion. This was done to ensure that sufficient cases of subsequent pregnancy would be available for the study of confounding variables. The supplemental sample was stratified by age and ethnicity to match the pool of women with subsequent pregnancies as determined by the record-linkage. The sample was combined for all aspects of data collection and processing, but excluded from analyses where the research design called for comparison of the original abortion and control samples.

Using available public records, commercial services, and personal contacts, we made every effort to locate the sample women. Once located, the women were asked to participate in an interview that would enable us to study methodological and substantive questions that could not be addressed by the record-linkage alone. Records of the location effort itself, however, constitute the data for examination of retention bias.

The first step in the research strategy was to comb available public records such as voter registrations, telephone directories, and city directories, for an address or telephone number. Whenever possible, a second source was used to verify the information, particularly if there was not a complete and direct listing of the woman's own name. The Hawaiian Telephone Company was most helpful in verifying whether a given name and address corresponded to their records for a party with an unlisted telephone number.

When a "good" address was found, a letter requesting the interview was sent. If the letter was returned by the post office, postal forwarding services were requested and the search continued. If the letter was not returned, the subject was assigned to an interviewer for telephone or personal contact. Some of these cases could no longer be reached at the address or telephone number listed, and the search continued for them.

When the readily available sources had been exhausted, several additional approaches were used. Two commercial services were tried. One, a telephone check-verification service, located very few names because its records contained only the names of people whose checks had been returned by banks as unnegotiable. The other, a commercial search firm linked to a chain of credit agencies, was moderately successful in locating women not found in the basic public records.

More effective than these services was the tactic of calling persons listed in the phone directory with the same last name and inquiring about the whereabouts of the subject. This was done whenever there were relatively few listings. The callers were careful to provide only minimal information about the purpose of the call, in order to protect the privacy of persons in the sample. The calls often reached a woman's relatives, who could either make direct contact or suggest another person who might know her whereabouts. Several deaths and out-of-state addresses were also reported. When no phone number was found, and particularly on the rural neighbor islands, an interviewer was sent to the last known address to inquire at the residence and in the neighborhood.

The location effort was conducted between 1978 and 1980, a minimum of four years and a maximum of ten after the event for which the woman had been sampled. It was terminated when all reasonable attempts to locate the missing subjects had been carried out and when the cost of further searches would have been prohibitive.

We are certain that many of the unlocated women are no longer in the state, even though their departure could not be verified. We are equally certain that many of the unlocated women are still in the state, but it was no longer reasonable to keep searching for them. Shortly after the location process ended, for example, one elusive subject became the subject of a front-page newspaper article.

Subjects who were found in the state were asked to participate in a personal interview on matters related to women's health and fertility. Case loss due to our failure to locate subjects, refusal, and semi-refusal is shown in Table 9. The semi-refusal category includes women who declined to be interviewed, but agreed to fill out a mailed questionnaire. After careful consideration, however, we decided that the amount of additional information that might be obtained from a mailed questionnaire did not warrant the expense. The interview sample for this part of the study contained 315 abortion cases and 393 control cases, plus 99 supplemental sample cases.

The interview protocol included a carefully collected fertility history, information on a variety of health and fertility-related topics, and special focus on each pregnancy and its outcome. Data were also collected on name changes and periods when the respondent was not living in the state. Most of the fertility history data relevant to the present analysis were collected by means of a time-line or life-history technique designed to facilitate recall of events by association and to maximize the accuracy of the dates of events.

The interviews were conducted by carefully selected and specially trained female interviewers. They were trained to encourage reporting of induced abortions and to be nonjudgmental about any fertility-related behavior reported. All interviews were conducted double-blind. Neither the interviewer nor the respondent knew why the respondent had been selected, or what the precise research questions were. These procedures protected the respondent's privacy and the neutrality of the interview, while encouraging complete and accurate reporting of fertility history.

Further details on the plan of this substudy are described elsewhere (Chung et al., 1981).

Retention rates

In this substudy we located 517 cases of the abortion cohort and 603 cases of the control sample who were ascertained to be definitely in the state of Hawaii at the time of the study. Altogether, 103 cases of the abortion cohort and 52 cases of the control were found to be either deceased or definitely out of the state (Table 10).

In order to assign the remainder of the sampled subjects to in-state or out-of-state status, two methods were used. These methods were described in detail in Chung et al. (1981). Briefly, the method referred

TABLE 9 Case loss from original samples due to loss to follow-up and interview refusal

	Location process					Interview acceptance			
Sample	Deceased	Found out of state	Lost to follow-up	Found in state	Total sample drawn	Refused	Agreed to mail questionnaire	Interviewed	Total cases found
Control									
Number	4	49	543	603	1,199	122	88	393	603
% of total	0.3	4.1	45.3	50.3	100	10.2	7.3	32.8	
% of cases found	*	*	*	*	*	20.2	14.6	65.2	100
Abortion									
Number	5	98	580	517	1,200	129	73	315	517
% of total	0.4	8.2	48.3	43.1	100	10.7	6.1	26.2	
% of cases found	*	*	*	*	*	25.0	14.1	60.9	100
Abortion supplement									
Number	0	18	104	151	273	31	21	99	151
% of total	0	6.6	38.1	55.3	100	11.4	7.7	36.3	
% of cases found	*	*	*	*	*	20.5	13.9	65.6	100

* Less than 1%.

TABLE 10 Location statuses in 1980 estimated by staff assignment and depreciation methods, by sample

	Abortion sample				Control sample			
	Staff assignment		Depreciation		Staff assignment		Depreciation	
Location status	N	%	N	%	N	%	N	%
In state								
Found in state	517	43.08	517	43.08	603	50.25	603	50.25
Probably in state	275	22.92	293	24.42	200	16.67	273	22.75
Subtotal	792	66.00	810	67.50	803	66.92	876	73.00
Not in state								
Deceased or found out of state	103	8.58	103	8.58	52	4.33	52	4.33
Probably out of state	305	25.42	287	23.92	345	28.75	272	22.67
Subtotal	408	34.00	390	32.50	397	33.08	324	27.00
Total	1,200	100.00	1,200	100.00	1,200	100.00	1,200	100.00

to as staff assignment was based on the subjective judgment of the project staff who were quite familiar with the local population. A case of unknown location status was assigned to one or the other class based on their best judgment. The method of assignment called depreciation is based on the principle that the probability of a subject's being in the state depreciates with succeeding years of our failure to locate her. The depreciation method has advantages in that it is objective and takes no other demographic factors into consideration in the process of assignment. Therefore, analysis of retention bias was based on the data classified by the method.

As Table 10 shows, the depreciation method generally yielded higher rates of being located in-state than the staff assignment method. Table 11 shows that Hawaii-born, non-Caucasians, and older women were more likely than others to be in the state. For a given group, the retention rate was expected to decrease with each succeeding year to the last year (1980) for this substudy. However, the critical period of concern should have coincided with the period of record-linkage, which ended in 1978.

Table 12 shows the estimated rates of in-state retention for the abortion and control samples by demographic characteristics for the record-linkage period. In general, the control sample had slightly larger in-state rates. At the end of the record-linkage period, 76.33 percent of the abortion sample and 80.58 percent of the control sample were estimated to be still residing in the state.

Factors associated with retention

As shown in Table 12, women born in Hawaii were most likely to have remained in the state throughout the record-linkage period, whereas women born on the U.S. mainland were most likely to have left, in both samples. Foreign-born women in the abortion sample were somewhat more likely than foreign-born control women to have left the state.

Birthplace in itself is not a critical factor for the analysis, but it is closely related to ethnicity. As expected, Caucasian women had a much higher rate of case loss than Japanese and Chinese or Hawaiian and part-Hawaiian women. The rates were similar in both samples, with slightly higher losses among all ethnic groups in the abortion sample.

The two samples show very similar rates of case loss for women

TABLE 11 Percentages of abortion and control samples estimated to be in state at end of 1980, by staff assignment and depreciation method, shown for selected variables

	Staff assignment			Depreciation		
Variable	Abortion	Control	Total	Abortion	Control	Total
Year of entry						
1970	63.34	72.25	67.78	64.67	74.33	69.83
1971	62.33	67.33	64.84	64.00	73.33	68.83
1972	66.34	66.78	66.55	68.33	70.67	69.83
1973	72.00	61.08	66.61	72.67	72.33	72.79
Place of birth						
Hawaii	81.34	89.38	85.31	79.67	87.67	83.61
Other U.S. state	49.37	32.94	41.73	53.67	51.31	52.71
Foreign	54.35	65.87	59.83	58.15	71.86	64.96
Unknown	42.86	53.92	52.04	52.38	62.75	61.79
Ethnicity						
Caucasian	48.54	41.37	45.31	65.63	67.26	66.25
Filipino	68.87	83.00	77.08	75.47	87.76	83.00
Hawaiian	81.32	82.69	82.09	87.35	90.38	89.04
Japanese/Chinese	84.56	91.09	87.20	87.58	93.56	90.00
Other	66.00	64.90	65.32	77.33	79.18	79.24
Age group						
< 20	64.49	65.44	64.84	67.39	72.22	69.18
20–24	63.46	60.48	61.88	64.32	69.37	65.58
25–29	60.32	71.88	67.00	63.89	75.36	70.52
30–34	83.21	77.56	80.28	79.56	80.95	79.93
34+	72.47	63.13	66.92	73.39	70.00	71.75

under 20 and over 29. The estimate shows a higher rate of case loss in the abortion sample for women in their 20s. This difference may partly reflect the estimation method's insensitivity to the large numbers of military dependents in the control sample, but some of the difference may be genuine.

The rate of retention of married women was virtually identical for the abortion and control samples. Women who were single at conception of the sampled event were more likely to remain in the state in the control sample, but less likely in the abortion sample. Separated,

TABLE 12 Estimated percentage of abortion and control samples in state to end of record-linkage period (1978), by place of birth, ethnicity, age, marital status, and year of entry into linkage

	Abortion		Control	
	N	%	N	%
Place of birth				
Hawaii	517	86.17	542	92.80
Other U.S. state	258	65.32	216	62.97
Foreign	128	69.57	134	80.24
Unknown	14	66.67	73	71.57
Ethnicity				
Caucasian	315	65.63	265	67.26
Hawaiian	145	87.35	188	90.38
Japanese/Chinese	261	87.58	189	93.56
Other	196	76.51	326	83.16
Age group				
<20	218	78.98	132	81.48
20–24	309	72.54	300	78.53
25–29	185	73.41	283	82.03
30–34	117	85.40	126	85.71
34+	87	79.82	124	77.50
Marital status				
Single	499	74.70	166	86.01
Married	312	79.39	716	80.63
Separated/divorced	104	75.36	13	81.25
Unknown	1	100.00	71	71.72
Year of entry				
1970	221	73.67	243	81.00
1971	217	72.33	242	80.67
1972	234	78.00	244	81.33
1973	244	81.33	239	79.67
Number of cases[a]	917		965	

[a] All numbers of cases were derived by rounding from weighted estimates.

divorced, and widowed women in the abortion sample were also less likely to have remained in the state.

In the control sample, there was no difference in the retention rate by year of entry in the record-linkage, but the abortion sample showed greater case loss among women who entered in the first two years. Again, some of the differential may be an artifact of the estimation procedure, but some of it may also reflect a genuine difference.

Overall, the demographic differences between the two estimated retained samples were not great. To a certain extent, the retention biases tended to reduce the known differences in the demographic composition of the original samples, making the retained samples more comparable. This observation is consistent with that of the part of the abortion cohort that had subsequent pregnancies, as discussed earlier. The two major factors of interest, age and ethnicity, were controlled for in the record-linkage data analyses. The results of the location analyses suggest that age and ethnicity controls are necessary not only because of the relation of these factors to the dependent variables in the analyses, but also because of the need to reduce the effect of possible retention bias between the two samples.

Analysis of variance was used to test whether women who left the state before the end of the record-linkage period differed significantly on a variety of fertility-related measures from those who remained. The results are shown in Table 13 for both samples and in Table 14 for the abortion sample alone.

The first analysis of variance (Table 13) provides two measures of retention bias. The first is whether there are any interaction effects involving location and sample, which would suggest a bias that might seriously affect the results of the comparison. There were no significant interactions involving location and either sample or ethnicity. The second measure is whether location has any direct or main effect; it had no significant effect on any of the dependent variables after adjustments were made for age, parity, ethnicity, and sample.

The results are the same when the in- and out-of-state groups are compared in the abortion sample alone. There were no significant effects of location, after adjustment for the effects of age, parity, and ethnicity (Table 14).

Although Table 13 shows no direct effect of location, there were significant differences between the abortion and control samples on all of the measures used except age at menarche. The same significant differences were found when the in- and out-of-state abortion samples were compared with the total control sample. Except for the two variables related to intercourse, however, the effects of all the variables on

TABLE 13 Analysis of variance showing relationship of location in or out of state to prior fetal loss, prior induced abortion, education, social class, age at menarche and at first intercourse, and frequency of intercourse

(Age and parity as covariates, ethnicity and sample as other factors)

Source of variation	Prior fetal loss	Prior induced abortion	Education	Social class	Age at menarche	Age at first intercourse	Frequency of intercourse
Covariates	0.01	0.01	0.01	0.01	0.05	0.01	*
Age	0.01	0.05	0.01	0.01	0.05	0.01	*
Parity prior to sampled event	*	*	0.01	0.01	*	0.01	*
Main effects	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Location	*	*	*	*	*	*	*
Sample	0.01	0.01	0.01	0.01	*	0.01	0.01
Ethnicity	*	*	0.01	0.01	0.01	0.01	*
Two-way interactions	*	*	*	0.05	*	*	*
Location X sample	*	*	*	*	*	*	*
Location X ethnicity	*	*	*	*	*	*	*
Sample X ethnicity	*	*	*	0.01	*	*	*
Three-way interactions	*	*	*	*	*	*	*
Location X sample X ethnicity	*	*	*	*	*	*	*
Number of cases	1,688	2,160	2,179	1,873	1,995	1,919	1,474

* Nonsignificant.

0.01 = Significant at 1% level.

0.05 = Significant at 5% level.

TABLE 14 Analysis of variance for abortion sample only showing relation of location in or out of state to selected variables

(Age and parity as covariates, ethnicity as additional factor)

Source of variation	Prior fetal loss	Prior induced abortion	Education	Social class	Age at menarche	Age at first intercourse	Frequency of intercourse
Covariates	0.01	0.01	0.01	0.01	0.01	0.01	*
Age	0.01	0.01	0.01	0.01	0.01	0.01	*
Parity	*	*	0.01	0.01	0.05	0.01	*
Main effects	*	*	0.05	0.01	0.01	0.01	*
Location	*	*	*	*	*	*	*
Ethnicity	*	*	0.01	0.01	0.01	0.01	*
Two-way interactions	*	*	*	*	*	*	*
Location X ethnicity	*	*	*	*	*	*	*
Number of cases	847	1,108	1,110	931	1,003	978	692

* Nonsignificant.

0.01 = Significant at 1% level.

0.05 = Significant at 5% level.

the outcome variables of interest to us in the comparisons between the abortion and control groups are allowed for by means of data stratification or logistic regression in the analysis of the main data to be presented. Furthermore, the importance of the intercourse variables on the major factors to be studied is questionable. Overall, the results of the analyses of retention bias strongly support the validity of the record-linkage data as a large and relatively unbiased subset of the original cohort of abortion cases. The changes that have occurred in the relationship of the abortion cohort to the two control samples appear to be minimal, and their confounding effects on the comparisons of the abortion and control samples can be allowed for by using appropriate controls in the data analysis.

Completeness of vital data reporting

A study of subsequent effects of induced abortion based on record-linked data assumes that the data base used is a complete record of relevant pregnancies, and that the record-linkage procedure is able to link each woman's available pregnancy records with accuracy and completeness. Incompleteness of the data base can arise in two ways. In the first, events of interest take place outside the confines of the reporting system; in the second, events that occurred within the limits of the reporting system fail to be reported. Two types of errors in the record-linkage procedure are failure of linkage and mismatch.

The design and method of analysis covering these aspects of the ancillary study are described in detail elsewhere (Chung et al., 1981). For analysis, the reproductive history reported by a respondent in the interview was compared, event by event, with that generated for her by the record-linkage. A weighting procedure was used to adjust the value of each case up or down from 1.0 to reflect the age and ethnic distribution of the retained sample for the record-linkage period.

In the abortion sample, 62.2 percent of women had at least one pregnancy after the sampled event, compared with 63.7 percent in the control sample. But there were gross differences in outcome types between the two samples. In the control sample, there were 81.6 percent births, 9.8 percent spontaneous abortions and pregnancy anomalies, and 8.6 percent induced abortions, whereas the corresponding rates for the abortion sample were 48.0 percent, 12.1 percent, and 39.9 percent, respectively. The higher rate of repeated induced abortions in the abortion sample and its implications have been discussed elsewhere (Steinhoff et al., 1979).

There are two kinds of incompleteness in reporting. One is the failure of a woman to report reproductive events in the interview that were previously recorded in the vital registration system. The other is the failure of the vital registration system to record known reproductive events. For the purpose of our study, based on the record-linkage, the second type is more serious. It is of interest that about a third of the women did not admit they had had a previous induced abortion, whereas no such omissions were observed for pregnancies ending in births. About 6 percent of spontaneous abortions were not reported by women. Women reported induced abortions as spontaneous abortions about as often as they made the reverse type of crossover. We have reported earlier, however, that vital statistics erroneously recorded 1.7 percent of induced abortions as spontaneous abortions (Chung et al., 1981). Among those induced and spontaneous abortions reported by women, dates of the events were recalled wrongly much of the time, though that discrepancy was negligible for births. Overall, the reporting of dates was quite accurate, the mean error being less than one week.

The vital statistics reporting system may miss events either because they took place outside the geographic area covered by the system, or because they occurred in the area but were not recorded. Although some degree of underreporting is to be expected in a vital statistics reporting system, either a large number of missing data on subsequent pregnancies or an unequal rate of underreporting in the abortion and control samples could call into question analyses based on the record-linked data.

To test for these potential biases, we compared all subsequent events reported by the women or by vital statistics ascertained through record-linkage, or both, for the 1970–78 period. We found some differences in completeness of reporting, by sample, as shown in Table 15. The differences were limited to the next pregnancy after the sampled event, as rates for pregnancies after the next event were nearly the same. In the abortion sample, 77.47 percent of next pregnancies were reported in vital statistics, compared with 91.23 percent of next pregnancies of controls. For all subsequent pregnancies combined, the figures were 79.50 percent and 87.53 percent, respectively. Within

TABLE 15 Pregnancies after sampled event, 1970–78, by sample, reporting status, and subsequent pregnancy order

	Next pregnancy				Pregnancies after next event				All subsequent pregnancies			
	Abortion		Control		Abortion		Control		Abortion		Control	
Reporting status	N	%	N	%	N	%	N	%	N	%	N	%
Reported in vital statistics[a]	136	77.47	216	91.23	85	83.26	107	80.75	221	79.50	323	87.53
Unreported												
Out of state	11	6.00	7	2.75	2	2.06	4	3.10	13	4.68	11	2.98
In state, unreported	29	16.53	14	6.01	15	14.69	21	16.15	44	15.83	35	9.49
All unreported	40	22.53	21	8.76	17	16.75	25	19.25	57	20.51	46	12.47
Number	176		237		102		132		278		369	

NOTE: Percentages based on weighted data.

[a] Includes events found in vital statistics after the woman reported them, but not previously linked.

both samples, however, roughly a third of the missing events occurred out of state, and two-thirds in the state.

Out-of-state events were presumably randomly distributed across pregnancy outcomes and occurred for reasons independent of the pregnancies themselves. Unreported in-state events, on the other hand, were strongly biased in favor of incomplete pregnancies, particularly induced abortions and uncomplicated early spontaneous abortions. Beginning in 1974, early induced abortions were no longer restricted to hospitals. Although state law requires reporting of all fetal deaths, regardless of gestation or cause, only events that require some use of hospital facilities are routinely reported. This factor, combined with the greater predilection of abortion recipients than of others to terminate their next pregnancy by induced abortion, accounts for much of the differential between the two samples.

If allowance were made for the known degree of underreporting of induced abortions by women, the differential would become even greater. As shown in Table 16 (adjusted induced abortion total), it increased to 73.91 percent versus 90.38 percent for next pregnancies.

Most analyses of the record-linked data were based on subsequent births and spontaneous abortions, with only indirect accounting for the disproportionate incidence of induced abortion. When the induced abortion cases are removed from the comparison, both samples are found to have had about the same proportions of unreported births and spontaneous abortions. The percentage of next events reported increases to 85.58 percent in the abortion sample and 91.74 percent in the control sample for next pregnancies (Table 16, total not reporting induced abortions). For the next eligible pregnancy–excluding induced abortions but taking the next birth after an induced abortion–the rates of reporting are again similar: 87.70 percent for the abortion sample and 91.56 percent for the controls.

Of particular importance for the study is the reporting of subsequent spontaneous abortions. In both samples, the rate of reporting spontaneous abortions varies with the method of determining the next event. Although the number of cases is rather small and the results must be interpreted with caution, there is no systematic evidence of differential reporting of subsequent spontaneous abortions in the abortion sample that could bias analyses based on the record-linked data in a particular direction. Rather, the results of the investigation of record-linkage error strengthen the study's finding of no difference between

TABLE 16 Reporting status of all pregnancies after sampled event, 1970–78, by pregnancy outcome and subsequent pregnancy order, with adjustment for women's underreporting of induced abortions

	Abortion				Control			
	In VS	Not in VS	Total	% reported	in VS	Not in VS	Total	% reported
Next pregnancy								
Induced abortion	48	25	73	65.86	16	4	20	79.85
Spontaneous abortion	10	10	20	49.06	13	11	23	55.95
Live birth	79	5	83	94.48	187	7	194	96.61
Total	136	40	176	77.47	216	21	237	91.23
Adjusted induced abortion	48	33	81	59.26	16	5	21	76.19
Adjusted total	136	48	184	73.91	216	23	239	90.38
Total not reporting induced abortions	89	15	104	85.58	200	18	218	91.74
Next eligible outcome								
Spontaneous abortion	13	10	23	56.52	13	12	25	52.00
Birth	94	5	99	94.95	193	7	200	96.50
Total	107	15	122	87.70	206	19	225	91.56

NOTE: Data include out-of-state pregnancies reported by women. All calculations are based on weighted data; consequently totals may vary because of rounding, and percentages may not correspond exactly to rounded numbers in cells.

VS—vital statistics.

the abortion and control samples in the rate of subsequent spontaneous abortion.

The number of cases of pregnancy anomalies such as ectopic pregnancy and hydatidiform mole (abnormalities of placenta with grapelike vesicles) was too small to evaluate in the same manner. Rates of reporting for live births differed slightly for next pregnancies but were identical for all subsequent pregnancies. Reporting rates for induced abortions were most dissimilar, but the adjusted rates for all subsequent pregnancies were very close. These comparisons again make it apparent that the overall differences in reporting were primarily due to the high incidence of repeat abortions of the next pregnancies of women in the abortion sample.

Completeness and accuracy of record-linkage

Even if the data base is adequate, the quality of the analysis depends upon the ability of the record-linkage procedure to match all events of the same woman (absence of linkage failures), and not to link together events that happened to different women (absence of mismatches). Our record-linkage procedure used several criteria to establish a correspondence between two vital statistics records. The primary match was made on a woman's maiden name, but her birthdate, ethnicity, and other characteristics such as married name were used to verify the match. Because of the many points of potential human error in the creation of the vital statistics records themselves, a certain margin of error had to be permitted for each criterion.

Mismatches. All true mismatches detected by the substudy were due to legal adoption. Hawaii law requires alteration of the birth certificate when a child is adopted. Consequently, a record-linkage procedure based primarily on the mother's maiden name will initially link the births of adopted children and any other pregnancies of the adopting mother.

Legal adoption actually causes two types of error: linking of the reproductive history of the adopting mother with a birth that she did not experience, and failure to link the reproductive history of the natural mother with that particular birth. This problem was identified during the sampling phase of the interview substudy, when the staff accidentally discovered indications of adoptions. Ten such cases were identified, and both women were included in the sample for location purposes. The study eventually located and interviewed four adopting

TABLE 17 Completeness of record linkage, by sample and pregnancy out-

Pregnancy outcome	Next pregnancy						
	Abortion				Control		
	Linked	Not linked	Total	% linked	Linked	Not linked	Total
Induced abortion	45	3	48	93.69	14	2	16
Spontaneous abortion	10	0	10	100.00	13	0	13
Birth	75	4	79	94.64	183	4	187
All outcomes	129	7	136	94.70	210	6	216

NOTE: Percentages calculated on weighted data: numbers rounded to whole numbers.

mothers and three natural mothers, but no matched pairs. All evidence relating to adoption linkages has been destroyed. In all cases, the woman reported the adoption in the interview; two of the three natural mothers reported the birth. For the purposes of evaluating record-linkage error, the adopting mothers were included in the sample and the natural mothers were excluded, since that pattern corresponds to the sample as drawn from vital statistics records. The four adoptions produced five mislinks to other pregnancies—three prior pregnancies and two subsequent. If the adoptions themselves are considered as mislinked events, then the rate of mislinkage in the control sample due to adoption is about 1 percent.

The three natural mothers who were located reported seven subsequent pregnancies. Two of these additional pregnancies were not recorded in vital statistics and therefore were not linkage failures. Because matched pairs were not available, it is not possible to calculate a precise estimate of the rate of failure to link owing to legal adoption. On the basis of this limited evidence, it might be assumed that failure to link occurs with at least the same frequency as mislinkage.

Linkage failure. If the record-linkage procedures were extremely accurate because they successfully rejected mislinks, they were likely also to have rejected or missed some true links. Cases of failure to link events of the same woman were identified when an event reported by a woman in the interview was subsequently found in the vital statistics records, even though it had not previously been linked.

The overall rates of successful linkage of the sampled event with all come for next pregnancy and all pregnancies except sampled event

	All pregnancies except sampled event							
	Abortion				Control			
% linked	Linked	Not linked	Total	% linked	Linked	Not linked	Total	% linked
86.90	86	6	92	93.48	25	2	27	92.59
100.00	16	1	17	94.12	38	0	38	100.00
97.99	183	11	194	94.33	355	5	360	98.61
97.27	285	18	303	94.06	418	7	425	98.35

prior and subsequent events recorded in vital statistics were slightly lower for the abortion sample than for the controls, 94.06 and 98.35 percent, respectively, as shown in Table 17. If allowance is made for the hidden linkage failures due to adoption, the difference decreases by at least 25 percent. The lowest rate of linkage in both samples was for induced abortions, where the two rates were 93.48 percent and 92.59 percent for the abortion and control samples, respectively. The differential between the two samples was caused primarily by the lower rate of successful linkage of births to women in the abortion sample. There was also a difference in successful linkage of spontaneous abortions, but the numbers were too small to affect the overall rates.

For all next-pregnancy outcomes, the rate of successful linkages was 94.7 percent in the abortion sample and 97.27 percent in the control sample. If the hidden failures due to adoption are considered, the rates were probably extremely close.

Causes of linkage failure. Although the primary record-linkage was based on the woman's maiden name, in some cases the record for a particular event contained only a married name. The marriage and divorce records of 1970–78 were cross-checked, but not all changes of marital status happened in the state, and not all of those that did were caught in the hand-checking process. In addition, names were often spelled differently or recorded differently, and initials were sometimes used. Many variations were caught by extensive hand-cleaning of the record-linkage, but inevitably some were missed. In other cases, the link was rejected because not enough supporting information matched to override the discrepancy.

Changes of name, or the recording of events under different name combinations, accounted for 80 percent of the linkage failures in the abortion sample. Most of the remainder were technical failures such as rejection for lack of supporting data, or absence of a critical intermediate link as in the case of reported neonatal death without the corresponding report of birth. There was only one failed linkage for no apparent reason.

In the control sample, about a third of the records failed to link because of name changes. The remainder were not linked because of spelling variations. The control linkage was not hand-cleaned as completely as the abortion linkage. Had the control linkage been cleaned as carefully, some spelling discrepancies would have been caught and either accepted or rejected on the basis of supporting data.

Misclassification of control subjects

Virtually every type of error in the data base or the record-linkage procedure could result in the misclassification of a woman with a prior induced abortion as a control subject, although all individuals linked with the original abortion cohort and the subsequent registry of elective abortions of the State Health Department were excluded from the control sample.

Limitations in the quality of the data base used for the record-linkage accounted for nearly all of the misclassified cases in the record-linked control sample. Aside from one unrecorded in-state abortion within the record-linkage period, all of these errors were induced abortions that occurred prior to the beginning of the record-linkage period.

Record-linkage errors proved to be a minor problem for the linked control sample. We detected no failures to link a woman in the control sample to a prior induced abortion that was recorded in vital statistics.

Although the potential sources of misclassification error are myriad, the control sample appears to have been relatively uncontaminated. In the record-linked control sample, only 3.0 percent of the women were probably misclassified.

Control-sample contamination of this magnitude is unlikely to have biased the results of the main record-linkage study. The adverse outcomes being studied are relatively rare events and the differences found between the samples minimal.

Confounding variables

Some of the variables of interest to us as indicators of subsequent pregnancy risk (spontaneous abortion, low birth weight, short gestation, and congenital malformations) are also known to be affected by other factors, such as maternal smoking, alcohol consumption, and diabetes. Since the main study does not consider these factors in the analysis, an independent check of possible association of these factors with induced abortion was needed for interpreting the results of the main study. The interview substudy investigated the possibility that such factors might confound the relationship between induced abortion and these indicators of risk in subsequent pregnancies. For this purpose we compared the frequency of these attributes in the abortion and control samples.

Cases used for the analysis included all subsequent pregnancies in the abortion and control interview samples described earlier and in the special supplemental sample drawn from the pool of induced abortion cases that had already been linked to subsequent pregnancies in the vital statistics records. (The supplemental sample was added to ensure that sufficient cases of subsequent pregnancies of women with an abortion history would be available for analyses such as the present one. Location and interviewing procedures were the same as for the other samples.) The two samples were similar in size (490 pregnancies in the abortion sample and 406 in the control sample).

Interview respondents were asked about the amount of cigarette, cigar, and pipe smoking they had done, and the frequency and amount of their alcohol consumption during each trimester of every pregnancy. They were also asked whether they were diabetic, and if so, the age at onset and type of treatment they received. From these data, it was possible to identify the type of diabetes and specify at which pregnancies a woman was either diabetic or prediabetic.

Smoking. The proportion of women who smoked during subsequent pregnancies was low overall but differed by ethnic group. It ranged from a low of 20 percent among Japanese and Chinese women to a high of 40 percent among Hawaiian and part-Hawaiian women. Smoking was more common among women under 25, and decreased sharply thereafter. Only three women reported smoking cigars or pipes, and two of those also smoked cigarettes. (Marijuana smoking is not included in this analysis, because the research literature that prompted the investigation is limited to tobacco smoking, and the assumption is that the observed effects are due in large part to nicotine.)

There were no significant differences between the abortion and control samples in the proportion of women who smoked, except for the Hawaiian group, in which the abortion sample smoked more. When only next pregnancies after the sampled event were considered, this difference was not significant. We conclude that the difference was an artifact caused by the higher subsequent pregnancy rate of young Hawaiian women with a history of induced abortion. We expected age-associated confounding to be removed in the main study by stratification or multivariate analysis.

Drinking. The proportion of women who consumed alcohol during subsequent pregnancies also varied by ethnic group. It ranged from a low of 15 percent among Japanese and Chinese women to a high of 50 percent among Caucasian women. Heavy drinking (more than an estimated 80 ounces of alcohol per trimester) was found among less than 3 percent of the sample, and the numbers were too small for detailed statistical analysis. The proportion of women who consumed alcohol increased with age, but heavy drinkers were broadly distributed across age and ethnic categories. Women reported slightly less drinking in each successive trimester. There were no significant differences in drinking patterns between the abortion and control samples in any trimester of pregnancy.

Diabetes. No significant difference emerged between samples in the incidence of diabetes in subsequent pregnancies. In the next pregnancy, 4.36 percent of women in the abortion sample had diabetes, compared with 4.17 percent of women in the control sample. Rates were essentially the same at each successive pregnancy. Hawaiian and part-Hawaiian women had higher rates of adult onset and gestational diabetes in both samples. These two types of diabetes accounted for over 95 percent of all diabetes-affected pregnancies.

In sum, there is no reason to suspect that differential rates of smoking, alcohol consumption, or diabetes confounded the comparisons between the abortion and control samples in subsequent spontaneous abortion, birthweight, gestation length, or congenital anomalies.

METHODS OF ANALYSIS

Given the basic aims of the study, it was highly desirable that the data be subjected to a uniform statistical treatment. The nature of our data would not allow such a convenient treatment, however. Various factors had to be considered in determining the appropriate methods of analysis. First, information in fetal death certificates, especially about early fetal deaths, was much less complete than that in birth certificates. For example, reproductive histories of women were missing altogether from certificates of fetal death that occurred less than 16 weeks after conception. Second, most of the pregnancy outcomes of interest in our study were represented by indicator variables such as low birth weight, presence of pregnancy complications, or spontaneous abortion, whereas such a variable as birth weight itself could be considered as a continuously distributed variable. Third, we had to allow for confounding variables in the analysis. Adjustment for these confounders presents no special analytical problem for a continuously distributed trait because the multiple regression method should serve as an adequate tool for covariance analysis. But the adjustment becomes increasingly difficult with indicator variables as the number of confounding factors increases (Miettinen, 1976).

Aside from coping with the specific problems described above, on general principle methods of analysis must possess sufficient intelligibility so that the result can be understood readily by a large number of readers and retained with a reasonable degree of statistical efficiency. For this reason, we chose the following strategy for analyzing the data.

Two sources of data necessarily call for different approaches. Vital records constituted the major source of data for our study, in which no matching of extraneous variables took place. The hospital data provided more refined information and were based on a matched-pair design. To analyze the data from vital records, we used the following stepwise procedures. For discrete outcome variables, the first step consisted of a simple χ^2 analysis using the Mantel-Haenszel (1959) method. Stratification of the data was based on racial group, maternal age at the time of event (subsequent event for the abortion cohort), and parity (number of prior live births). The samples consisted of five racial groups, four age groups, and two parity groups, giving rise to $5 \times 4 \times 2 = 40$ strata for the analysis. The Mantel-Haenszel method is a technique for analyzing a combination of 2 × 2 contingency tables, each of which is composed of:

	Prior abortion	No prior abortion	
Positive outcome	A_i	B_i	N_{1i}
Negative outcome	C_i	D_i	N_{2i}
	M_{1i}	M_{2i}	T_i

where A_i, B_i, C_i, and D_i are the observed numbers in the respective cells in the ith stratum with the marginal totals of N_{1i}, N_{2i}, M_{1i}, and M_{2i} and $T_i = A_i + B_i + C_i + D_i$. The overall test of the null hypothesis of no association is given by $\chi^2 = (|\Sigma A_i - \Sigma E(A_i)| - ½)^2 / \Sigma V(A_i)$ with one degree of freedom, where $E(A_i) = N_{1i}M_{1i}/T$ and $V(A_i) = N_{1i}N_{2i}M_{1i}M_{2i}/T_i^2(T_i - 1)$. The overall relative risk may be estimated by $\psi = \Sigma(A_iD_i/T_i)/\Sigma(B_iC_i/T_i)$.

The method provides a powerful test of the null hypothesis, with a single degree of freedom allowing for a small number of important confounding variables. Furthermore, it can be readily understood and the result can be directly related to a given table. But the procedure does not allow for other possible confounding variables. Therefore, we did not take rejection (or acceptance) of the null hypothesis, based on the preceding test, as final unless it was supported by further tests.

Parity grouping for the comparison presents an interesting problem. Nulliparous women from the abortion group who had a subsequent pregnancy could be contrasted to nulliparous control women or to control women with parity 1, depending on whether an induced abortion was viewed as a live birth or not. To accommodate the alternative interpretations of induced abortion, we did two parity groupings in forming strata. In the first case, the abortion and control samples were compared within parity classes of 0 or 1 or more parity, whereas in the second case, nulliparous abortion women were contrasted to parity 1 control women, and parity 1 or more abortion women contrasted to parity 2 or more control women.

The χ^2 analysis was followed by multivariate logistic regression analysis (Truett et al., 1967) that included other possible confounding variables in addition to the variables considered above. According to the method, the probability of having a positive outcome can be expressed as $\dfrac{1}{1 + e^{-(a+\Sigma\beta_i x_i)}}$, where e, a, and β_i are respectively the base of the natural logarithm, a constant, and the coefficient of the ith variable influencing the risk of positive outcome of the variable under study. The variables (x_i) include the exposure and confounding variables. The β_i represents also the coefficient of the linear discriminant function discriminating between the groups of positive and negative outcomes. Under this model, the independent effect of induced abortion can be tested by the significance of β_I, corresponding to history of induced abortion. Furthermore, as history of induced abortion was coded as 1 for positive and 0 for negative, e^{β_I} becomes an estimate of relative risk for the abortion women, allowing for the confounding variables. Other variables considered were year of pregnancy outcome, maternal age, race coded by four binary variables taking Caucasians as the base, resident island (Oahu = 1, otherwise = 0), pregnancy order of event, marital status of the mother at the time of the outcome (married = 0, not married now = 1), and mother's education in years.

Methods analyzing birth weight, gestation length, fetal death, and ectopic pregnancy deviated from the procedure discussed earlier. We analyzed birth weight and gestation length, represented as continuous variables, by the multiple regression method by introducing a number of dummy variables, to be discussed below. For fetal death, we substituted marital status for parity in the Mantel-Haenszel χ^2 analysis because information on the latter was missing from early fetal death records. For the χ^2 analysis of ectopic pregnancy, maternal race was not considered because of the limited number of cases in the abortion group; therefore, there were only eight strata (4 age groups × 2 marital groups) for the analysis.

More elaborate analyses were performed on the matched hospital data because of higher quality and limited sample size of the data. They were done in several stages. At the initial stage, we compared the abortion and control groups by means of McNemar's χ^2 test (Fleiss, 1973) applicable to matched data. Next we analyzed the matched data by multivariate logistic regression, as was done for the vital registration data. Mother's education was not included in the logistic model, however.

We further studied possible abortion effects by making comparisons between specific subgroups of the abortion and control groups selected on the basis of reproductive history of the women, with due allowance for the matched variables. This analysis included comparisons of pregnancy outcome of the nulliparous cohort women who had had only one previous induced abortion with the control pregnancies of three groups: women who had had no prior pregnancy, those who had had only one prior spontaneous abortion, and those who had experienced only one prior live birth. These comparisons were of special importance because the majority of women who elect abortion have only one and these control subgroups provide a meaningful base for comparison with the cohort women.

We studied factors associated with induced abortion at the time of procedure in relation to pregnancy outcome by comparing subgroups of the abortion group with the control, stratifying by multivariate confounder scores proposed by Miettinen (1976). Essentially, this method enables a comparison of the two groups with adjustment for confounding variables. For this purpose, we transformed the computed linear discriminant function for a particular outcome, described earlier, to the scoring function by fixing the exposure variable (prior abortion history) at the level of control (no abortion history). Thus the confounder scores were "standardized" at the level of subjects with no history of induced abortion. The score was computed for each subject and these scores served as a basis for constructing five strata so that each stratum had approximately an equal number of subjects with a history of induced abortion. Finally, we computed relative risk for each stratum and carried out the overall test of association using the Mantel-Haenszel χ^2 method.

The confounder variables considered were the same ones included in the multivariate logistic regression analysis for the hospital data. Factors studied in relation to abortion were maternal age and gestation weeks at the time of procedure, number of previous induced abortions experienced, type of procedure, use of laminaria, and abortion complications. Maternal age was age at first induced abortion if there were more than one. Other factors pertained to the most recent induced abortion. Abortion complications were coded as present if one or more of the following conditions were observed after the previous termination of pregnancy: hemorrhage of 300 cc. or more, uterine perforation, adverse reaction to oxytocin or anesthesia, cervical laceration, retained secundines, and failed abortion with first procedure.

FINDINGS

Spontaneous fetal loss

For the analysis, spontaneous fetal loss was classified into three types on the basis of completed gestation length: first-trimester (⩽ 14 weeks), second-trimester (15–27 weeks), and third-trimester (⩾ 28 weeks) losses. We first present the results separately for the three types and then discuss them together. All of major Mantel-Haenszel χ^2 analyses of the main body of data were based on 40 strata (five racial groups, four age intervals, and two marital status classes), although the tables shown were stratified only by age and marital status for ease of presentation.

First-trimester Spontaneous Fetal Loss

Table 18 shows first-trimester abortions of the two samples stratified by maternal age and marital status at the time of outcome. There were 3,764 and 93,857 valid observations for the abortion and control samples, respectively. Of these, the respective proportions of first-trimester fetal loss were 6.85 and 6.17 percent. As tested by the Mantel-Haenszel χ^2, the difference was not significant ($\chi^2 = 1.11$, $P = 0.29$), the estimated relative risk being 1.08. The relative risk estimated directly from the data (0.0685/0.0617) was 1.11.

Because of apparent differences between married and unmarried women in the degree of association between abortion history and first-trimester fetal loss, we analyzed the data separately for the two groups. For married women there was no difference between the abortion and control groups, the loss rate being 5.06 and 5.75 percent, respectively ($\chi^2 = 0.26$, $P = 0.61$, relative risk = 0.95). The situation was quite different, however, for unmarried women; the abortion group had a significantly higher risk of first-trimester loss as indicated by the rates of 13.52 percent and 8.51 percent ($\chi^2_1 = 6.90$, $P = 0.009$, relative risk = 1.34).

TABLE 18 First-trimester spontaneous fetal loss of subsequent pregnancies of abortion and control groups, by age and marital status

Age group and marital status	Abortion				Control			
	Fetal loss	No fetal loss	Total	Proportion	Fetal loss	No fetal loss	Total	Proportion
< 20								
Unmarried	18	180	198	0.0909	403	5,979	6,382	0.0631
Married	6	266	272	0.0221	339	8,987	9,326	0.0363
20–24								
Unmarried	48	290	338	0.1420	450	4,288	4,738	0.0950
Married	46	1,061	1,107	0.0416	1,321	26,662	27,983	0.0472
25–29								
Unmarried	28	146	174	0.1609	192	1,751	1,943	0.0988
Married	40	1,012	1,052	0.0380	1,399	24,083	25,482	0.0549
> 29								
Unmarried	14	75	89	0.1573	172	1,067	1,239	0.1388
Married	58	476	534	0.1086	1,516	15,248	16,764	0.0904
Total	258	3,506	3,764	0.0685	5,792	88,065	93,857	0.0617

$\chi^2_1 = 1.11$.

$P = 0.29$.

Relative risk = 1.08.

TABLE 19 Estimated coefficients of multivariate logistic function and significance test for first-trimester fetal loss: all vital data

Variable	Coefficient	Standard error	*z*
Constant	-4.023		
Year of outcome	-0.015	0.006	-2.65*
Woman's age	0.076	0.003	30.00†
Race			
Hawaiian or part-Hawaiian	-0.519	0.038	-13.53†
Filipino	-0.390	0.039	-9.95†
Oriental	-0.375	0.037	-10.16†
Other	-0.431	0.052	-8.32†
Resident island	0.504	0.035	14.29†
Current marital status	0.944	0.039	24.42†
History of induced abortion	0.102	0.068	1.49

Relative risk = $e^{0.102}$ = 1.11.

* Significant at 0.01 level.

† Significant at 0.001 level.

Table 19 shows the result of the logistic regression analysis. It is of interest to note that every covariate included in the model was significantly associated with the risk of first-trimester fetal loss. With all of the covariates allowed for, history of induced abortion showed no significant relationship with the risk of early fetal death. The relative risk estimated from the regression was 1.11 (z = 1.49, P = 0.14), which is in close agreement with the preceding estimate based on the stratified data.

The preceding analysis adjusts for only race, maternal age, and marital status, and most of the information was derived from vital registration records. An important variable not considered in the analysis is parity or pregnancy order because of incompleteness of such information in fetal death records reported to the Health Department. Therefore, further analysis of refined data assumes special importance for spontaneous fetal death. Our study based on the hospital data is fully described elsewhere (Chung et al., 1982a). The abortion and control samples were pair-matched by race, age, and time of pregnancy out-

TABLE 20 Comparisons of spontaneous loss rates from matched

Spontaneous losses by trimester	Abortion +, control +	Abortion +, control −	Abortion −, control +	Abortion −, control −
First	19	212	165	3,020
Second	1	75	77	3,263
Third	0	16	21	3,379

* Significant at 0.025 level.

a. Confidence limits (CL) 95%.

come (± one month) in those data. Table 20 shows the distribution of four combinations of outcome between the abortion and control samples, where a plus sign indicates the presence of first-trimester fetal loss and a minus sign the absence of the outcome. The association of fetal loss with history of induced abortion was significant as tested by McNemar's χ^2 method ($\chi^2_1 = 5.61$, $P = 0.02$). The associated odds ratio was 212/165 = 1.28 and the relative risk 1.26. But the increase in the estimated relative risk over that of the main body of data was due largely to a lower rate of fetal loss in the control group as indicated by 6.8 versus 5.4 percent for the abortion and control samples, respectively (Table 20), whereas the corresponding rates from the main body of data were 6.9 and 6.2 percent, respectively (Table 18). The discrepancy in the controls was probably due to a difference in the mean parity.

The result of logistic function analysis of first-trimester fetal loss for the hospital data is shown in Table 21. The model includes residence island, pregnancy order of the event, and current marital status of the mother in addition to the three matched variables of year of the event, maternal age, and race. When all of the covariates were allowed for, history of induced abortion showed no significant association with early fetal death. The estimated relative risk for the abortion cohort was 1.10, which was nearly identical to that estimated from the logistic regression of the unmatched main body of data.

Table 22 shows the matched comparisons of spontaneous fetal loss rates for pregnancies of women with a history of only one induced abortion (A1) with the three subgroups of control pregnancies: those preceded by only one spontaneous abortion (S1), only one live birth (P1), and no previous live birth (P0). In these comparisons, the origihospital data

Total number of pairs	X^2_1	Odds ratio and CL[a]	Proportion in abortion group	Proportion in control group	Relative risk
3,416	5.61*	1.28(1.02-1.55)	0.068	0.054	1.26
3,416	0.01	0.97(0.66-1.28)	0.022	0.023	0.97
3,416	0.43	0.76(0.27-1.26)	0.005	0.006	0.76

nally matched variables remained matched, resulting in considerable reduction in sample sizes. Thus the data for the A1 and S1 groups were too small for a valid comparison. None of the comparisons between the A1 and P1 groups or between the A1 and P0 groups showed significant differences in their rates. The estimated relative risks for

TABLE 21 Estimated coefficients of multivariate logistic function and significance test for spontaneous first-trimester fetal loss: hospital data

Variable	Coefficient	Standard error	z
Constant	2.083		
Year of outcome	-0.093	0.037	-2.49*
Woman's age	0.071	0.013	5.49†
Race			
Hawaiian or part-Hawaiian	-0.452	0.147	-3.07†
Filipino	-0.161	0.164	-0.98
Oriental	0.054	0.143	0.38
Other	-0.430	0.228	-1.88
Resident island	0.006	0.139	0.04
Pregnancy order	0.044	0.038	1.18
Current marital status	1.207	0.147	8.23†
History of induced abortion	0.094	0.107	0.88

Relative risk = $e^{.094}$ = 1.10.

* Significant at 0.05 level.

† Significant at 0.01 level.

TABLE 22 Matched-pair comparisons of spontaneous fetal loss (+) and relative risks (RR) for specific combinations of reproductive history

Matched pairs	First-trimester	Second-trimester	Third-trimester
Abortion cohort			
A1			
+	1	0	0
–	39	40	40
Total	40	40	40
p	0.0250	0	0
Control			
S1			
+	3	1	0
–	37	39	40
Total	40	40	40
p	0.0750	0.0250	0
X^2_1	0.25	0	
RR ± S.E.	0.33±0.38		
Abortion cohort			
A1			
+	15	4	1
–	318	329	332
Total	333	333	333
p	0.0450	0.0120	.0030
Control			
P1			
+	15	5	0
–	318	328	333
Total	333	333	333
p	0.0450	0.0150	0
X^2_1	0.04	0	
RR ± S.E.	1.00±0.39	0.80±0.54	
Abortion cohort			
A1			
+	34	13	1
–	500	521	533
Total	534	534	534
p	0.0637	0.0243	.0019
Control			
P0			
+	27	18	4
–	507	516	530
Total	534	534	534
p	0.0506	0.0337	.0075
X^2_1	0.65	0.52	0.80
RR ± S.E.	1.29±0.35	0.72±0.26	0.25±0.28

first-trimester fetal loss accompanied by large standard errors were 1.00 (C.L. 0.23 and 1.77) and 1.29 (C.L. 0.60 and 1.98) for the A1 versus P1 and A1 versus P0 comparisons, respectively.

The results of testing specific factors associated with the most recent induced abortion are summarized in Table 23, which shows relative risk (RR) based on the Mantel-Haenszel method as applied to the data stratified by the multivariate confounder scores. The scores were derived from the discriminant function shown in Table 21. The data were grouped into five strata. Each subgroup of the cohort pregnancies characterized by a factor at previous induced abortion (e.g., use or non-

TABLE 23 Adjusted relative risks for first-trimester spontaneous fetal loss associated with previous induced abortion (IA) factors

Factors	Relative risk	X^2_1
Age at first IA		
< 20	0.95	0.06
20–24	1.30	3.79
25–29	1.01	0.004
> 29	1.62	3.59
Number of IAs		
1	1.15	1.56
> 1	1.01	0.003
Gestation weeks at last IA		
< 9	1.40	6.83†
9–12	0.93	0.23
> 12	1.03	0.004
IA procedure		
D&C	0.97	0.0006
Suction	1.06	0.14
Saline	0.90	0.06
D&C + suction	1.33	3.98*
Use of laminaria		
No	1.14	1.16
Yes	1.10	0.29
Abortion complications		
No	1.15	1.56
Yes	0.92	0.02

* Significant at 0.05 level.

† Significant at 0.01 level.

use of laminaria) was compared with the entire control group, comprising 3,416 observations, to test the association with one degree of freedom. Among six factors characterizing induced abortion—age at first induced abortion, number of previous induced abortions, gestation length at time of procedure, abortion procedure, use of laminaria, and abortion complications—we detected significant associations between the risk of first-trimester spontaneous abortion and both use of D&C + suction as the abortion procedure and short gestation length at time of induced abortion (< 9 weeks). The respective relative risks were 1.33 ($\chi^2_1 = 3.98, P = 0.046$) and 1.40 ($\chi^2_1 = 6.83, P = 0.009$). The D&C + suction procedure consisted of suction followed by sharp curettage and was practiced more commonly in the early years after the legalization of induced abortion.

Given the suggested association between the risk of early fetal loss and both abortion method and gestation stage at the time of induced abortion, we decided to check the consistency of the association and allow for separation of the effects of confounding variables. Because of the controversy involved, use of laminaria and number of prior induced abortions were also investigated further.

Table 24 shows the unadjusted rates of fetal loss during the first trimester by method of abortion procedure. The upper panel pertains to second pregnancies of women whose only previous pregnancies

TABLE 24 First-trimester spontaneous fetal loss (SA), by method of previous abortion procedure

Type of data and SA or no SA	D&C	Suction	D&C + suction	Other	Total
Only prior pregnancy terminated by induced abortion, 1971–76					
SA	11	34	41	12	98
No SA	208	673	484	189	1,554
Total	219	707	525	201	1,652
p	0.0502	0.0481	0.0781	0.0597	0.0593
All subsequent pregnancies, 1971–78					
SA	63	151	152	35	401
No SA	713	1,972	1,862	490	5,037
Total	776	2,123	2,014	525	5,438
p	0.0812	0.0711	0.0755	0.0667	0.0737

were terminated artificially; the analysis thereby removes possible complicating factors associated with other previous pregnancies. The highest frequency of first-trimester fetal loss (0.0781) was among women who had had the D&C + suction procedure (χ^2_1 = 4.87, P = 0.03), and there was no evidence of heterogeneity among other procedures (χ^2_2 = 0.41, P = 0.52). The association disappeared, however, when the sample size was increased to include all repeated pregnancies for the study period as shown in the lower panel of Table 24 (χ^2_3 = 1.59, P = 0.21).

Table 25 shows the relationship of completed gestation weeks at time of last induced abortion with first-trimester spontaneous loss. This subset of data again corroborates the earlier finding of a significant association of gestation time with early fetal loss (χ^2_1 = 9.36, P = 0.002). Pregnancies occurring after induced abortion performed at less than nine completed weeks of gestation had about a 55 percent greater risk of first-trimester spontaneous abortion (RR = 1.55) than pregnancies preceded by induced abortion performed at a later stage of pregnancy. The trend persisted in all subsequent pregnancies during 1971–78; the χ^2 value was 10.33 (P = 0.001) and the relative risk 1.43, when "other" types of procedure were excluded from the analysis (Table 26).

Table 27 compares the rates of spontaneous fetal loss during the first trimester between pregnancies of the cohort women whose last induced abortions were accompanied by laminaria for cervical dilation and another group in which laminaria was not employed. Although the risk of pregnancy loss tended to be higher for the pregnancies following induced abortion in which no laminaria was used, none of the associations proved to be significant (χ^2_1 = 0.40, P = 0.53); the overall relative risk was 1.12.

We also compared the rates of early fetal loss in a group of pregnancies preceded by only one previous induced abortion and another preceded by two or more induced abortions among women who had had two or more previous pregnancies (Table 28). No significant differences were detected in fetal loss rates between the two groups. The significance of these findings will be discussed in the concluding part of this section.

TABLE 25 First- and second-trimester spontaneous fetal loss (SA), by pregnancy order, number of gestation weeks at previous induced abortion, and abortion procedure

Trimester, pregnancy order, and abortion procedure	< 9 weeks				⩾9 weeks			
	SA	No SA	Total	Prop.	SA	No SA	Total	Prop.
First trimester								
Second pregnancy								
D&C	6	92	98	.0612	5	116	121	.0413
Suction	20	303	323	.0619	14	371	385	.0364
D&C + suction	20	218	238	.0840	21	266	287	.0732
Third or later pregnancy								
D&C	6	134	140	.0429	12	138	150	.0800
Suction	37	304	341	.1085	20	381	401	.0499
D&C + suction	32	285	317	.1009	23	358	381	.0604
Total	121	1,336	1,457	.0830	95	1,630	1,725	.0551
Second trimester								
Second pregnancy								
D&C	0	98	98	0	3	118	121	.0248
Suction	11	312	323	.0341	6	379	385	.0156
D&C + suction	0	238	238	0	7	280	287	.0244
Third or later pregnancy								
D&C	8	132	140	.0571	7	143	150	.0467
Suction	10	331	341	.0293	5	396	401	.0125
D&C + suction	3	314	317	.0095	14	367	381	.0367
Total	32	1,425	1,457	.0220	42	1,683	1,725	.0243

TABLE 26 First- and second-trimester spontaneous fetal loss (SA), all subsequent pregnancies during 1971–78, by number of gestation weeks at previous induced abortion and abortion procedure

Trimester and abortion procedure	<9 weeks				≥9 weeks			
	SA	No SA	Total	Prop.	SA	No SA	Total	Prop.
First trimester								
D&C	29	332	361	0.0803	34	381	415	0.0819
Suction	90	906	996	0.0904	61	1,066	1,127	0.0541
D&C + suction	81	844	925	0.0876	71	1,017	1,088	0.0653
Other	0	2	2	0	35	488	523	0.0669
All methods	200	2,084	2,284	0.0876	201	2,952	3,153	0.0637
Second trimester								
D&C	11	350	361	0.0305	8	407	415	0.0193
Suction	26	970	996	0.0261	15	1,112	1,127	0.0133
D&C + suction	15	910	925	0.0162	26	1,062	1,088	0.0239
Other	0	2	2	0	3	520	523	0.0057
All methods	52	2,232	2,284	0.0228	52	3,101	3,153	0.0165

TABLE 27 First- and second-trimester spontaneous fetal loss (SA), abortion, and abortion procedure

Trimester, pregnancy order, and abortion procedure	Abortion cohort			
	No laminaria			
	SA	No SA	Total	Prop.
First trimester				
Second pregnancy				
D&C	10	185	195	0.0513
Suction	26	457	483	0.0538
D&C + suction	29	317	346	0.0838
Other	11	144	155	0.0710
Third or later pregnancy				
D&C	17	253	270	0.0630
Suction	43	509	552	0.0779
D&C + suction	37	474	511	0.0724
Other	5	76	81	0.0617
Total	178	2,415	2,593	0.0686
Second trimester				
Second pregnancy				
D&C	3	192	195	0.0154
Suction	13	470	483	0.0269
D&C + suction	5	341	346	0.0145
Other	0	155	155	0
Third or later pregnancy				
D&C	14	256	270	0.0519
Suction	13	539	552	0.0236
D&C + suction	12	499	511	0.0235
Other	1	80	81	0.0123
Total	61	2,532	2,593	0.0235

Second-trimester Fetal Loss

Table 29 shows the second-trimester fetal loss rates for the abortion and control groups of the main study as stratified by maternal age and marital status. In contrast to our observations of first-trimester spontaneous loss, we found abortion and control groups in this case to be markedly similar, with the overall rates of 1.70 percent and 1.77 per-by pregnancy order, use of laminaria during previous induced

Laminaria				Control			
SA	No SA	Total	Prop.	SA	No SA	Total	Prop.
1	23	24	0.0417	53	1,025	1,078	.0492
8	216	224	0.0357				
12	167	179	0.0670				
1	45	46	0.0217				
1	19	20	0.0500	74	1,017	1,091	.0678
14	177	191	0.0733				
18	170	188	0.0957				
3	51	54	0.0556				
58	868	926	0.0626	127	2,042	2,169	.0586
0	24	24	0	12	1,066	1,078	.0111
4	220	224	0.0179				
2	177	179	0.0112				
1	45	46	0.0217				
1	19	20	0.0500	30	1,061	1,091	.0275
2	189	191	0.0105				
5	183	188	0.0266				
2	52	54	0.0370				
17	909	926	0.0184	42	2,127	2,169	.0194

cent, respectively ($\chi^2_1 = 0.03$, $P = 0.86$), the relative risk being 0.97. Furthermore, we could discern no difference between pregnancies of married and unmarried women when we analyzed them separately; $\chi^2_1 = 0.002$ and relative risk = 1.00 for the married and $\chi^2_1 = 0.11$ and relative risk = 0.90 for the unmarried group. This finding was clearly supported by the result of the logistic regression analysis, which produced an identical relative risk estimate (Table 30).

TABLE 28 First- and second-trimester spontaneous fetal loss (SA), by previous abortion procedure and number of previous induced abortions

Trimester and previous abortion procedure	One previous abortion				Two or more previous abortions			
	SA	No SA	Total	Prop.	SA	No SA	Total	Prop.
First trimester								
D&C	15	229	244	0.0615	3	40	43	0.0698
Suction	46	556	602	0.0764	9	115	124	0.0726
D&C + suction	43	463	506	0.0850	11	159	170	0.0647
Other	5	92	97	0.0515	3	34	37	0.0811
All methods	109	1,340	1,449	0.0752	26	348	374	0.0695
Second trimester								
D&C	13	231	244	0.0533	2	41	43	0.0465
Suction	12	590	602	0.0199	3	121	124	0.0242
D&C + suction	13	493	506	0.0257	3	167	170	0.0176
Other	2	95	97	0.0206	1	36	37	0.0270
All methods	40	1,409	1,449	0.0276	9	365	374	0.0241

TABLE 29 Second-trimester spontaneous fetal loss among abortion and control groups, by age and marital status

Age group and marital status	Abortion				Control			
	Fetal loss	No fetal loss	Total	Prop.	Fetal loss	No fetal loss	Total	Prop.
< 20								
Unmarried	5	193	198	0.0253	161	6,221	6,382	0.0252
Married	5	267	272	0.0184	123	9,203	9,326	0.0132
20–24								
Unmarried	7	331	338	0.0207	123	4,615	4,738	0.0260
Married	15	1,092	1,107	0.0136	389	27,594	27,983	0.0139
25–29								
Unmarried	3	171	174	0.0172	34	1,909	1,943	0.0175
Married	13	1,039	1,052	0.0124	399	25,083	25,482	0.0157
> 29								
Unmarried	3	86	89	0.0337	44	1,195	1,239	0.0355
Married	13	521	534	0.0243	392	16,372	16,764	0.0234
Total	64	3,700	3,764	0.0170	1,665	92,192	93,857	0.0177

$\chi^2_1 = 0.03$.

$P = 0.86$.

Relative risk = 0.97.

TABLE 30 Estimated coefficients of multivariate logistic function and significance test for second-trimester fetal loss: all vital data

Variable	Coefficient	Standard error	z
Constant	-4.489		
Year of outcome	-0.047	0.011	-4.43†
Woman's age	0.043	0.005	9.12†
Race			
Hawaiian or part-Hawaiian	-0.180	0.071	-2.53*
Filipino	-0.328	0.073	-4.51†
Oriental	-0.252	0.069	-3.67†
Other	-0.226	0.096	-2.35*
Resident island	0.339	0.065	5.18†
Current marital status	0.718	0.072	10.03†
History of induced abortion	-0.033	0.126	-0.26

Relative risk = $e^{-0.033}$ = 0.97.

* Significant at 0.05 level.

† Significant at 0.001 level.

Analysis of the matched hospital data also produced results consistent with those above ($\chi^2{}_1 = 0.01$, $P = 0.92$), including the same estimate of 0.97 for relative risk (Table 20). Table 31 shows the result of the logistic regression analysis of the data. Previous induced abortion was found to be unrelated to mid-trimester spontaneous abortion (relative risk of 0.88 estimated from the model). The hospital data were somewhat limited when the analysis considered parity and previous spontaneous abortion (Table 22). But we found no evidence to suggest that nulliparous women with a history of single induced abortion had a higher (or lower) risk of subsequent mid-trimester spontaneous abortion than women who had had one or no previous birth.

The six factors associated with previous induced abortion (age at abortion, number of induced abortions, gestation weeks at previous abortion, abortion procedure, use of laminaria, and complications) are examined in Table 32, which shows relative risks of spontaneous fetal loss for the abortion and control groups. None of the relative risks was significant. We did find mid-trimester fetal loss to be higher (but not significantly so) among women who had had the D&C procedure

TABLE 31 Estimated coefficients of multivariate logistic function and significance test for spontaneous second-trimester fetal loss: hospital data

Variable	Coefficient	Standard error	z
Constant	-1.159		
Year of outcome	-0.047	0.060	-0.78
Woman's age	0.023	0.021	1.09
Race			
Hawaiian or part-Hawaiian	-0.191	0.236	-0.81
Filipino	-0.518	0.262	-1.97*
Oriental	-0.370	0.229	-1.62
Other	-0.080	0.366	-0.22
Resident island	0.363	0.223	1.63
Pregnancy order	0.040	0.060	0.67
Current marital status	0.846	0.234	3.61†
History of induced abortion	-0.133	0.171	-0.78

Relative risk = $e^{-0.133}$ = 0.88.

* Significant at 0.05 level.

† Significant at 0.01 level.

(χ^2_1 = 2.50, $P = 0.11$); relative risk was 1.59. The difference was not evident, however, when analysis was confined to only those pregnancies preceded by a single prior pregnancy that had been deliberately terminated or when the analysis was based on all subsequent pregnancies (Table 33). The use of laminaria during the previous procedure was associated with a slightly lower rate of fetal loss (1.84 percent) than was nonuse (2.35 percent) among the abortion sample, but the difference was not significant (χ^2_1 = 0.17, $P = 0.68$) and the relative risk was 1.17 (Table 27). Further examinations of gestation time at last induced abortion and number of prior abortions jointly with abortion procedure showed no significant associations with subsequent mid-trimester spontaneous abortion, findings consistent with those presented in Tables 25, 26, and 28.

Third-trimester Fetal Loss

Because of generally low rates of third-trimester fetal loss, our study of this sequela suffers from small numbers of observations, especially

TABLE 32 Adjusted relative risks for second-trimester spontaneous fetal loss associated with factors of previous induced abortion (IA)

Factor	Relative risk	X^2_1
Age at first IA		
<20	1.09	0.08
20–24	0.70	1.94
25–29	0.99	0.01
>29	1.01	0.03
Number of IAs		
1	0.91	0.23
>1	0.80	0.19
Gestation weeks at last IA		
<9	0.91	0.10
9–12	0.96	0.005
>12	0.66	0.95
IA procedure		
D&C	1.59	2.50
Suction	0.88	0.25
Saline	0.52	1.03
D&C + suction	0.78	0.80
Use of laminaria		
No	0.94	0.05
Yes	0.76	0.70
Abortion complications		
No	0.86	0.66
Yes	1.32	0.31

in the abortion group. Only 14 cases of third-trimester fetal death were observed among 3,764 pregnancies of abortion cohort women (0.37 percent), in contrast to 632 among 93,857 pregnancies in the control sample (0.67%), as shown in Table 34. The difference was barely significant ($\chi^2_1 = 3.86$, $P = 0.05$), and the relative risk was 0.57, which is in the direction opposite to expectation if there were any adverse effect of prior induced abortion. Contrary to expectation, significant association was limited to pregnancies of the married group ($\chi^2_1 = 5.31$, $P = 0.02$, relative risk of 0.43, compared with $\chi^2_1 = 0.01$, $P = 0.92$, relative risk of 1.04 for the unmarried group). Lower risk for the abortion group persisted in the result of the multivariate logistic

TABLE 33 Second-trimester spontaneous fetal loss (SA), by method of abortion procedure

Type of data and SA or no SA	D&C	Suction	D&C + suction	Other	Total
Only prior pregnancy terminated by induced abortion, 1971–76					
SA	3	17	7	1	28
No SA	216	690	518	200	1,624
Total	219	707	525	201	1,652
p	0.0137	0.0240	0.0133	0.0050	0.0169
All subsequent pregnancies, 1971–78					
SA	19	41	41	3	104
No SA	757	2,082	1,973	522	5,334
Total	776	2,123	2,014	525	5,438
p	0.0245	0.0193	0.0204	0.0057	0.0191

regression analysis (Table 35), which produced borderline significance of the relative risk, 0.66 ($z = -2.04$, $P = 0.04$). To increase sample size, we included all repeat pregnancies of the same women in both samples for further analysis by the χ^2 method (Table 36). These data showed no longer statistically significant association between previous abortion and third-trimester fetal loss ($\chi^2{}_1 = 2.65$, $P = 0.10$); relative risk was 0.69.

The matched hospital data revealed no significant association ($\chi^2{}_1 = 0.43$, $P = 0.51$), although the estimated relative risk remained less than unity (0.76) (see Table 20). Table 37 shows the result of the logistic regression analysis, which is consistent with the above finding, the estimated relative risk being 0.81. The result of parity matched analysis also yielded no significant relationship between prior abortion and late fetal loss. None of the factors connected with previous abortion was found to be significantly related to the risk of late fetal death (Table 38), although the power of these tests is expected to be low. Further statistical treatment of this variable seemed unproductive because of the limited number of observations in the abortion group.

General Consideration

Our study on spontaneous fetal loss as a sequela of previous induced abortion suffers from a dilemma. Parity or pregnancy order is con-

TABLE 34 Third-trimester spontaneous fetal loss among abortion and control groups, by age and marital status

Age group and marital status	Abortion				Control			
	Fetal loss	No fetal loss	Total	Prop.	Fetal loss	No fetal loss	Total	Prop.
< 20								
Unmarried	1	197	198	0.0051	40	6,342	6,382	0.0063
Married	0	272	272	0	53	9,273	9,326	0.0057
20–24								
Unmarried	2	336	338	0.0059	33	4,705	4,738	0.0070
Married	4	1,103	1,107	0.0036	165	27,818	27,983	0.0059
25–29								
Unmarried	3	171	174	0.0172	14	1,929	1,943	0.0072
Married	3	1,049	1,052	0.0029	135	25,347	25,482	0.0053
> 29								
Unmarried	0	89	89	0	18	1,221	1,239	0.0145
Married	1	533	534	0.0019	174	16,590	16,764	0.0104
Total	14	3,750	3,764	0.0037	632	93,225	93,857	0.0067

$\chi^2_1 = 3.86$.

Significant at 0.05 level.

Relative risk = 0.57.

TABLE 35 Estimated coefficients of multivariate logistic function and significance test for third-trimester fetal loss: all vital data

Variable	Coefficient	Standard error	z
Constant	-5.729		
Year of outcome	-0.067	0.017	-3.98††
Woman's age	0.055	0.007	7.32††
Race			
Hawaiian or part-Hawaiian	0.112	0.113	0.99
Filipino	0.034	0.116	0.30
Oriental	-0.493	0.109	-4.50††
Other	-0.036	0.154	-0.23
Resident island	-0.071	0.105	-0.68
Current marital status	0.324	0.114	2.84†
History of induced abortion	-0.411	0.202	-2.04*

Relative risk = $e^{-0.411}$ = 0.66.

* Significant at 0.05 level.

† Significant at 0.01 level.

†† Significant at 0.001 level.

sidered to be an important covariate that must be allowed for in any analysis of fetal mortality. Our sample of subsequent pregnancies derived from the vital registration system was sufficiently large but deficient in information on the reproductive history of women with a history of early spontaneous abortion. In contrast, the hospital data had reliable information on reproductive history but suffered from a smaller sample size. Under these circumstances, the results from the two sources of data must complement each other.

No significant association was detected between induced abortion and the risk of second-trimester fetal loss from any source of data. Furthermore, no particular factor characterizing prior induced abortion was found to be associated significantly with the risk of second-trimester fetal loss in subsequent pregnancies.

In summarizing three major worldwide studies, Tietze (1981) noted that two out of seven comparisons showed significantly higher rates of mid-trimester fetal loss among nulliparous abortion women than

TABLE 36 Third-trimester spontaneous fetal loss of all subsequent pregnancies, including repeat pregnancies, among abortion and control groups, by age and marital status

	Abortion				Control			
Age group and marital status	Fetal loss	No fetal loss	Total	Prop.	Fetal loss	No fetal loss	Total	Prop.
< 20								
Unmarried	3	226	229	0.0131	44	6,552	6,596	0.0067
Married	1	320	321	0.0031	64	10,721	10,785	0.0059
20–24								
Unmarried	2	447	449	0.0045	35	4,984	5,019	0.0070
Married	5	1,559	1,564	0.0032	208	37,917	38,125	0.0055
25–29								
Unmarried	4	230	234	0.0171	15	2,067	2,082	0.0072
Married	5	1,555	1,560	0.0032	187	37,708	37,895	0.0049
> 29								
Unmarried	0	115	115	0	18	1,304	1,322	0.0136
Married	2	798	800	0.0025	238	25,710	25,948	0.0092
Total	22	5,250	5,272	0.0042	809	126,963	127,772	0.0063

$\chi^2_1 = 2.65$.

$P = 0.10$.

Relative risk = 0.69.

TABLE 37 Estimated coefficients of multivariate logistic function and significance test for spontaneous third-trimester fetal loss: hospital data

Variable	Coefficient	Standard error	*z*
Constant	-0.320		
Year of outcome	-0.090	0.121	-0.74
Woman's age	0.104	0.042	2.47*
Race			
Hawaiian or part-Hawaiian	0.079	0.477	0.17
Filipino	-0.318	0.530	-0.60
Oriental	-0.526	0.462	-1.14
Other	0.183	0.740	0.25
Resident island	-0.388	0.450	-0.86
Pregnancy order	-0.191	0.122	-1.56
Current marital status	1.069	0.473	2.26*
History of induced abortion	-0.214	0.346	-0.62

Relative risk = $e^{-0.214}$ = 0.81.

* Significant at 0.05 level.

among control women of gravidity 1. One of these comparisons involved a group of women in California who had had two or more induced abortions (Harlap et al., 1979), and the other study was carried out in an Eastern European country (WHO Task Force, 1979). Those data represent situations distinctly different from the one in this study. Tietze's summary raises an interesting question, however, about the power of a test to detect a specified difference. To examine this question, we calculated the power of detecting a doubled risk (RR = 2) from our data, using the conditional power function (Miettinen, 1968). The power calculated from the data in Table 20 reached nearly 100 percent, indicating that in no way could we miss such a magnitude of effect of induced abortion if it was present in our data. Therefore, if there were any effect, it must indeed be small.

It has been hypothesized that instrumental dilation followed by curettage (D&C) causes cervical incompetence and causes higher risk of second-trimester fetal loss (Harlap et al., 1979; WHO Task Force, 1979). Our data provide no convincing support for the hypothesis.

TABLE 38 Adjusted relative risks of third-trimester spontaneous fetal loss associated with factors of previous induced abortion (IA)

Factors	Relative risk	$X^2{}_1$
Age at first IA		
< 20	0.79	0.06
20–24	0.80	0.09
25–29	0.25	1.37
> 29	0.92	0.06
Number of IAs		
1	0.61	1.45
> 1	1.68	0.36
Gestation weeks at last IA		
< 9	0.54	0.97
9–12	0.73	0.28
> 12	1.13	0.004
IA procedure		
D&C	na	na
Suction	0.90	0.001
Saline	1.04	0.11
D&C + suction	0.79	0.07
Use of laminaria		
No	0.61	1.26
Yes	1.04	0.02
Abortion complications		
No	0.62	1.33
Yes	1.77	0.30

na—not applicable.

First, comparison of the D&C procedure with the control and with other types of abortion procedure within the abortion cohort women did not reveal a significantly higher risk of mid-trimester spontaneous abortion. Second, the use of laminaria at the time of the prior induced abortion did not substantially reduce the risk of mid-trimester spontaneous loss from that of cases in which no laminaria was used. It is noteworthy, however, that the estimated relative risk was in the direction expected from the hypothesis. 1.59 for D&C procedure in relation to the control pregnancies.

The situation was somewhat different in the case of first-trimester fetal loss. There, the risk appeared to be higher for the abortion sample. The magnitude of the difference depended upon the sample and method of estimation, estimates of the relative risk ranging from 1.08 to 1.29. In view of the relatively small excess risk and inconsistent statistical significance, we cannot attach too much importance to these values.

One important factor has never been considered in studies of this nature. It relates to aspects of competition between spontaneous fetal loss and induced abortion among women who are determined not to carry an unwanted pregnancy to term. These pregnancies result in either spontaneous abortion or induced abortion. In this kind of study when the outcome is spontaneous abortion, it is included as an observation in the sample whether the study has a case-control or a cohort design, whereas the pregnancy is excluded from the sample if it is deliberately terminated. This problem need not complicate a comparison of rates of spontaneous loss in a cohort study if the exposure and control groups have a comparable proportion of such women. It is known, however, that the proportion of unwanted pregnancies is higher among women with a history of induced abortion (Tietze, 1981; Steinhoff et al., 1979). This fact would tend to increase the rate of spontaneous abortion in the abortion cohort.

Knowing that the competition reduces the spontaneous abortion rate to about a half of the level without competition (Potter et al., 1975), we can derive the expressions of unbiased frequency of spontaneous abortion (SA) among all pregnancies resulting in SA or live births (LB), in the absence of an adverse effect of prior induced abortion, as

$$s'_c = P[\mathrm{SA}|(\mathrm{SA\ or\ LB})] = \frac{s(1+p_0)}{2p_0 + s(1-p_0)} \quad \text{for the control group and}$$

$$s'_a = P[\mathrm{SA}|(\mathrm{SA\ or\ LB})] = \frac{s(1+p_1)}{2p_1 + s(1-p_1)} \quad \text{for the abortion cohort,}$$

where s is the general rate of spontaneous abortion applicable to both groups, p_0 is the proportion of wanted pregnancies in the control, and p_1 is the proportion of wanted pregnancies in the abortion cohort. Wanted pregnancy is the complement of unwanted pregnancy. Their respective odds are

$$\frac{s'_i}{1-s'_i} = \frac{s(1+p_0)}{2p_0(1-s)} \text{ and } \frac{s'_a}{1-s'_a} = \frac{s(1+p_1)}{2p_1+s(1-p_1)}.$$

Then the relative risk (odds ratio) under either cohort or case-control design can be expressed as $(p_0 + p_0p_1)/(p_1 + p_0p_1)$.

As pointed out earlier (Chung, 1981), the relative risk under this condition increases with difference between p_0 and p_1 when p_0 is greater than p_1, as shown below.

	$p_0 = .80$			$p_0 = .75$			$p_0 = .70$		
p_1	.70	.60	.50	.65	.55	.45	.60	.50	.40
Relative risk	1.08	1.19	1.33	1.09	1.21	1.38	1.10	1.24	1.44

The relative risk also becomes larger as $1-p_0$ increases.

Unfortunately, no reliable data on p_0 and p_1 are available for other populations to judge the degree of bias associated with data from studies that report increased mid-trimester spontaneous abortion risk. But we do have independent estimates of these parameters from our ancillary study. These are $p_0 = 0.93$ and $p_1 = 0.65$ estimated from Table 17. The substitution of these values into the formula yields a relative risk of 1.22, which is within the range of the values observed in the main study. Therefore, we conclude that the small amount of excess risk in first-trimester spontaneous abortion observed for the abortion cohort women can be explained largely by the sampling problem attributable to higher probability of unwanted pregnancy among women who had one or more prior induced abortions.

The observation that a higher risk of first-trimester fetal loss for the abortion group was limited to pregnancies of unmarried women needs explanation. One or both of the following factors could be responsible. First, the socioeconomic factors may have been unevenly distributed between the abortion and control samples in this group, confounding the outcome. Second and more plausibly, an unmarried woman whose unwanted pregnancy is terminated by spontaneous abortion is less likely to marry than an unmarried woman who has a normal pregnancy. The finding that the excess risk was more pronounced among younger women (Table 18) provides support for this hypothesis.

How then do we interpret the observed greater risk of first-trimester spontaneous abortion associated with early gestation stage (< 9 weeks) at time of previous induced abortion? The observation is in conflict with the general expectation that an abortion procedure performed at an early stage of pregnancy involves fewer complications and therefore is less likely to increase the risk of complications during a subsequent pregnancy than is an abortion performed at a later stage of gestation. It is not clear whether the apparent excess risk connected with early induced abortion is the result of statistical confounding yet to be explained or is a biological effect. In any event, if we allow for the sampling bias described above, the excess risk attributable to the early abortion is expected to be small. The magnitude of its possible effect can be seen by the following calculations. If we take the relative risk of 1.22 as the base for comparison, the increase due to early abortion is 1.40 – 1.22 = 0.18. The estimate would have a large standard error.

Harlap et al. (1979) found an increase in the risk of second-trimester spontaneous abortion among nulliparous women with a history of prior induced abortion, particularly among those who had had multiple induced abortions. Levin et al. (1980) observed significant increases in the risk of both first- and second-trimester spontaneous pregnancy losses among women who had experienced more than one induced abortion. None of these nor other studies adjusted for the bias in the estimates of relative risk due to the difference in the proportions of wanted pregnancies between the study and control groups. For this reason, their estimates of relative risk must be considered overestimates of the true relative risk of spontaneous fetal loss for the abortion group. As pointed out elsewhere (Chung, 1981), overestimation of the relative risk becomes more serious for women who have had repeated abortions because the probability of unwanted pregnancy increases with the number of induced abortions (Tietze, 1981). Thus it is likely that at least part of the increased risks of spontaneous pregnancy loss observed by those investigators may be explained by the bias.

The observed relationship between induced abortion and third-trimester fetal loss is somewhat puzzling. Although not all associations tested were significant, all estimates of the relative risk were less than unity and showed a slightly lower rate for the abortion group. It is difficult to suppose that induced abortion itself has a beneficial effect in reducing third-trimester fetal loss. There are at least two plausible explanations for the observation. First, it is possible that possible confounders not allowed for the present analysis may have produced the type I statistical error, producing a false positive association. Second, we could interpret the result as a consequence of the slightly increased risk of first-trimester spontaneous abortion on the hypothesis that a constant proportion of fetuses is subject to spontaneous death, the time of occurrence depending on when an adverse intrauterine condition is encountered. Under this hypothesis, such susceptible fetuses may be eliminated early in pregnancy by women who obtain an induced abortion, thereby reducing the probability of third-trimester fetal death.

Ectopic pregnancy

Ectopic pregnancy in the vital registration records was identified by ICDA (International Classification of Diseases, Adapted) code 769.3 in the field of standard (spontaneous) fetal death. Because of the generally low incidence of the condition, we modified our method of analysis somewhat. Analysis of the vital records was based on information stratified only by maternal age and marital status. A special report on the subject of ectopic pregnancy has been published elsewhere (Chung et al., 1982b). Therefore, this section includes much of the information presented in the earlier report. Our conclusion remains the same, though minor differences exist in the results of some analysis because of changes in the data set.

Table 39 shows the distribution by maternal age and marital status of ectopic pregnancies as reported in the vital data, for the abortion and control samples. The frequencies of ectopic pregnancies among all pregnancies resulting in deliveries or spontaneous abortions were 0.57 and 0.49 percent for the abortion and control groups, respectively. The overall incidence rate of 0.49 percent was slightly higher than that estimated for England and Wales in 1972 (Beral, 1975), where the incidence was estimated as 0.43 percent as ascertained from hospital discharge records. In our sample the risk of ectopic pregnancy increased consistently with maternal age, in agreement with the British study. Pregnancies of unmarried women were clearly at higher risk of being ectopic. The overall frequencies of ectopic pregnancy for the married and unmarried groups were 0.42 and 0.85 percent, respectively. The relationship with marital status suggests the importance of sociological factors in influencing outcome of a pregnancy. But the Mantel-Haenszel χ^2 test showed no evidence of association between history of induced abortion and subsequent ectopic pregnancy (χ^2_1 = 0.003, $P = 0.96$), the relative risk being 1.18. The result remained

TABLE 39 Ectopic pregnancies among abortion and control groups, by age and marital status

Age group and marital status	Abortion group				Control group			
	Ectopic	No ectopic	Total	% ectopic	Ectopic	No ectopic	Total	% ectopic
< 20								
Married	0	290	290	0	7	9,688	9,695	0.07
Unmarried	1	217	218	0.46	22	6,830	6,852	0.32
20–24								
Married	3	1,175	1,178	0.25	87	28,937	29,024	0.30
Unmarried	6	367	373	1.61	45	5,111	5,156	0.87
25–29								
Married	4	1,100	1,104	0.36	135	26,370	26,505	0.51
Unmarried	3	181	184	1.63	38	2,091	2,129	1.78
> 29								
Married	5	555	560	0.89	122	17,453	17,575	0.69
Unmarried	1	96	97	1.03	24	1,356	1,380	1.74
Total	23	3,981	4,004	0.57	480	97,836	98,316	0.49

$\chi^2_1 = 0.003$.

$P = 0.96$.

Relative risk = 1.18.

TABLE 40 Estimated coefficients of multivariate logistic function and significance test for ectopic pregnancy: all vital data

Variable	Coefficient	Standard error	z
Constant	-7.289		
Year of outcome	0.085	0.020	4.22*
Woman's age	0.092	0.009	10.26*
Race			
Hawaiian or part-Hawaiian	-0.907	0.136	-6.66*
Filipino	-0.705	0.139	-5.07*
Oriental	-0.455	0.131	-3.47*
Other	-0.146	0.184	-0.79
Resident island	0.618	0.125	4.93*
Current marital status	1.383	0.137	10.08*
History of induced abortion	0.228	0.242	0.94

Relative risk = $e^{0.228}$ = 1.26.

* Significant at 0.001 level.

the same when the analysis was applied to a larger set of data that included repeated pregnancies of both groups ($\chi^2{}_1 = 0.27$, $P = 0.60$); in that case the estimated relative risk was 1.30. The result of the logistic regression analysis is given in Table 40 and is consistent with the preceding findings, the nonsignificant relative risk being 1.26.

The overall incidence of 0.54 percent estimated from the matched-pair hospital data was slightly higher than the earlier estimate of 0.49 percent, demonstrating a high degree of reliability of ascertainment of cases through the vital records (Table 41). No significant associa-

TABLE 41 Matched pairs, by combination of ectopic versus nonectopic pregnancy outcomes

	Control group		
Abortion group	Ectopic	Nonectopic	Total
Ectopic	0	22	22
Nonectopic	15	3,379	3,394
Total	15	3,401	3,416

NOTE: Frequency of ectopic pregnancy for abortion group = 0.64%; frequency of ectopic pregnancy for control group = 0.44%. Relative risk = 1.47.

tion was detected between history of induced abortion and subsequent ectopic pregnancy ($\chi^2_1 = 0.97$, $P = 0.32$); estimated relative risk was 1.47.

Table 42 shows the result of the multivariate logistic function analysis. Interestingly, among the nine covariates considered, *only* maternal age and marital status were found to be significantly related to ectopic pregnancy. Pregnancy order did not contribute significantly to the risk of ectopic pregnancy, though an apparent association was in the negative direction. History of induced abortion showed no significant relationship ($z = 0.94$, $P = 0.35$) to the resulting relative risk of $e^{0.330} = 1.39$, a finding consistent with the results from the earlier analysis. Because of the extremely small numbers of cases involved, the inconclusive result of parity-matched analysis is not presented here.

Notwithstanding the observed absence of significant association between history of induced abortion and ectopic pregnancy, we proceeded to examine possible relationships between factors associated with the induced abortion procedure and the risk of subsequent ectopic pregnancy, since the earlier tests of association may have missed

TABLE 42 Estimated coefficients of multivariate logistic function and significance test for ectopic pregnancy: hospital data

Variable	Coefficient	Standard error	*z*
Constant	-14.110		
Year of outcome	0.061	0.123	0.50
Woman's age	0.155	0.043	3.64*
Race			
Hawaiian or part-Hawaiian	-0.158	0.484	-0.33
Filipino	0.145	0.538	0.27
Oriental	0.294	0.468	0.63
Other	0.891	0.750	1.19
Resident island	0.101	0.456	0.22
Pregnancy order	-0.214	0.124	-1.73
Current marital status	1.997	0.480	4.16*
History of induced abortion	0.330	0.351	0.94

Relative risk = $e^{0.330} = 1.39$.

* Significant at 0.01 level.

TABLE 43 Adjusted relative risks of ectopic pregnancy associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
<20	0.92	0.04
20–24	1.71	1.42
25–29	1.23	0.003
>29	1.91	0.29
Number of IAs		
1	1.51	1.06
>1	0.59	0.01
Gestation weeks at last IA		
<9	1.73	1.38
9–12	1.24	0.06
>12	1.02	0.13
IA procedure		
D&C	0.97	0.12
Suction	1.81	1.64
Saline	1.86	0.11
D&C + suction	1.09	0.005
Use of laminaria		
No	1.45	0.72
Yes	1.28	0.04
Abortion complications		
No	1.43	0.77
Yes	1.02	0.25

small effects of specific factors related to induced abortion. The result of the analysis of relative risk is given in Table 43. None of the six factors studied could be shown to be associated with subsequent ectopic pregnancy. We further examined several factors individually (Tables 44–47). None of the χ^2 values was found to be significant. But a test of association between ectopic pregnancy and abortion complications approached significance at the 5 percent level ($\chi^2_1 = 3.54$, $P = 0.06$), the estimated relative risk being 2.45 for the group of abortion women (Table 48).

TABLE 44 Ectopic pregnancy, by abortion procedure

Procedure	All pregnancies	Ectopic pregnancies	% ectopic
D&C	780	6	0.77
Suction	2,158	16	0.74
D&C + suction	2,037	4	0.20
Other	601	4	0.67
All procedures	5,576	30	0.54

$X^2_3 = 7.07$.

$P = 0.07$.

TABLE 45 Ectopic pregnancy, by use of laminaria at previous induced abortion

Use of laminaria	All pregnancies	Ectopic pregnancies	% ectopic
Yes	1,580	6	0.38
No	3,996	24	0.60
Total	5,576	30	0.54

$X^2_1 = 1.03$.

$P = 0.31$.

TABLE 46 Ectopic pregnancy, by number of previous induced abortions (IAs)

Number of IAs	All pregnancies	Ectopic pregnancies	% ectopic
1	4,707	26	0.55
⩾2	869	4	0.46
Total	5,576	30	0.54

$X^2_1 = 0.12$.

$P = 0.73$.

TABLE 47 Ectopic pregnancy, by number of gestation weeks at previous induced abortion

Gestation weeks	All pregnancies	Ectopic pregnancies	% ectopic
<9 weeks	2,330	17	0.73
≥ 9 weeks	3,245	13	0.40
Total	5,575	30	0.54

$\chi^2_1 = 2.74$.
$P = 0.10$.

TABLE 48 Ectopic pregnancy, by whether complications were associated with previous abortion procedure

Complications	All pregnancies	Ectopic pregnancies	% ectopic
Yes	423	5	1.18
No	5,151	25	0.49
Total	5,574	30	0.54

$\chi^2_1 = 3.54$.
$P = 0.06$.

Table 49 shows the rates of ectopic pregnancy among pregnancies followed by major postabortion complications. The numbers of ectopic pregnancy cases were small under the subgrouping, but it is evident that the risk of ectopic pregnancy was markedly higher for the groups of women who had infection or retained secundines than for women without reported postabortion complications. The relative risks were 2.78 and 6.65 for the infection and retained secundines groups, respectively. Since retained secundines are known to increase the probability of infection, these two conditions are likely to represent the same etiological factor in relation to ectopic pregnancy. We therefore pooled the two conditions to compare them with the remaining conditions, including no complications, for further analysis (Table 50). Analysis of the 2 × 2 contingency table showed a highly significant association between ectopic pregnancy and the presence or absence of the two types of complications (χ^2_1 with continuity

TABLE 49 Ectopic pregnancy, by major type of complications associated with previous abortion

Type of complications	Ectopic pregnancy	No ectopic pregnancy	All pregnancies	% ectopic
None	25	5,126	5,151	0.49
Infection	1	73	74	1.35
Retained secundines	3	90	93	3.23
Hemorrhage	0	73	73	0
Cervical laceration	1	111	112	0 89
Other	0	71	71	0
All types	30	5,544	5,574	0.54

TABLE 50 Ectopic pregnancy, by infection or retained secundines and other complications

Complication	Ectopic pregnancy	No ectopic pregnancy	All pregnancies
Infection or retained secundines	4	163	167
Other	26	5,381	5,407
All complications	30	5,544	5,574

$X^2_c = 7.80$.

Significant at 0.005 level.

correction = 7.80, $P = 0.005$). The corresponding relative risk was 5.08. The rate of ectopic pregnancy among pregnancies without these complications was 0.48 percent, which was similar to that of the control group, or 0.49 percent.

The present investigation has clearly demonstrated that for pregnancies of women with a history of induced abortion, an increase in the risk of ectopic pregnancy depends strictly on whether or not the prior induced abortion was accompanied by complications such as infection or retained secundines, which increase the probability of subsequent infection. The corollary is that if induced abortion imposes no additional risk of these complications over other types of pregnancy outcomes, we would not expect to observe an excess risk of ectopic pregnancy among women with a history of prior induced abortion.

Unfortunately, we have no comparable information on the status of infection or retained placenta in the control group. But the overall observation that the women with a history of induced abortion did not have a significantly greater risk of ectopic pregnancy than the control group suggests that the specific postabortion complications were of minor consequence, if any, in increasing the incidence of extrauterine implantation in the abortion group under the conditions prevailing in Hawaii. These complications accounted for only 3 percent of the previous induced abortions in our data.

The contrary finding of positive association between history of induced abortion and ectopic pregnancy in Greece (Panayotou et al., 1972) could well be explained on the basis of a difference in postabortion complications, particularly since induced abortion is illegal in that country. It is also noteworthy that there was a significant increase in the stillbirth rate in Greece among women who had had a prior induced abortion (Pantelakis et al., 1973), in contrast to our finding in Hawaii.

Two factors tend to complicate the comparison of rates of ectopic pregnancy for women with prior induced abortion with a control group, even in the absence of a true adverse effect of induced abortion. They are related to the use of an intrauterine device (IUD) by women and the method of estimating the frequency of ectopic pregnancy cases.

First, some researchers have found that the probability of having ectopic pregnancy is higher among women who conceive with an IUD *in situ* than among other women (Tietze and Lewit, 1970; Seward et al., 1972; Vessey et al., 1974), although this point is disputed by others (Sivin, 1979; Ory, 1981). Furthermore, an earlier study of spontaneous abortion based on hospital data in Hawaii (Chung et al., 1982a) showed that there were twice as many IUDs *in situ* among pregnancies of women with a history of induced abortion than among the control group; the respective frequencies were 1.23 and 0.64 percent. To the extent that the experience of prior induced abortion is confounded with conception in the direction observed when an IUD is *in situ*, the incidence of ectopic pregnancy is overestimated for the abortion group. Because of low frequency of IUD *in situ* in the general population, however, the effect on the incidence of ectopic pregnancy may be expected to be small.

The second problem arises from the sampling procedure used in ascertaining ectopic pregnancy cases. As was done in this study, the incidence of ectopic pregnancy is usually computed as the proportion of cases among all pregnancies resulting in live birth and spontaneous fetal death, excluding subsequent induced abortions. Such a procedure tends to overestimate the rate of ectopic pregnancy for the abortion group. This problem arises because, compared with the control group, a smaller proportion of subsequent pregnancies results in delivery or spontaneous abortion owing to the already discussed higher rate of repeated induced abortions among the abortion group and to the fact that ectopic pregnancy is classified as spontaneous fetal death. The net result is that in the abortion group disproportionately more ectopic pregnancies are included in the numerator than in the denominator, thereby inflating the frequency and leading to a higher estimate of relative risk, even in the absence of effect of induced abortion. The quantitative relationship of this problem with estimation of the relative risk of spontaneous abortion has been presented elsewhere (Chung, 1981) and was further described in the previous section.

The consideration of these factors suggests that a relative risk estimate higher than unity can be expected in the absence of any adverse effect of induced abortion on subsequent pregnancy. Our observed values of nonsignificant relative risk are within the range expected. We therefore conclude that induced abortion has little or no effect on the risk of ectopic pregnancy in subsequent reproduction, if it is performed under generally favorable conditions.

Short gestation

We defined short gestation as completed gestation length of less than 37 weeks. The possible effect of induced abortion on short gestation was studied in two ways: first, by examining proportions of pregnancies characterized by short gestation and, second, by investigating mean gestation length. For the present analysis, only live births of gestation length of 20 weeks or more were considered. As with analysis of spontaneous abortion and ectopic pregnancy, pregnancy outcomes with multiple births, repeat pregnancy, or unknown maternal race were excluded from the analysis.

Table 51 shows short gestation and mean gestation length by maternal age and parity. Parity was grouped into nulliparous (parity = 0) and parous (parity ⩾ 1). Shorter gestation length tended to be associated with increasing parity as seen in both the proportion of short-

TABLE 51 Short gestation among abortion and control groups, by age and parity

(Parity classified as 0 or 1+ for both groups)

Age group and parity	Abortion group					Control group				
	Short gest.	No short gest.	Total	Prop.	Mean	Short gest.	No short gest.	Total	Prop.	Mean
< 20										
0	37	351	388	0.0954	39.758	1,585	11,104	12,689	0.1249	39.395
1+	6	39	45	0.1333	38.667	279	1,589	1,868	0.1494	39.175
20–24										
0	75	824	899	0.0834	39.808	1,622	18,051	19,673	0.0824	39.795
1+	38	382	420	0.0905	39.776	924	9,582	10,506	0.0879	39.730
25–29										
0	40	602	642	0.0623	39.835	789	11,035	11,824	0.0667	39.831
1+	47	445	492	0.0955	39.648	1,004	12,397	13,401	0.0749	39.755
> 29										
0	9	154	163	0.0552	39.656	401	3,666	4,067	0.0986	39.369
1+	35	336	371	0.0943	39.563	1,087	10,507	11,594	0.0938	39.461
Total	287	3,133	3,420	0.0839	39.732	7,691	77,931	85,622	0.0898	39.647

$\chi^2_1 = 0.97$.

$P = 0.32$.

Relative risk = 0.94.

gestation pregnancies and the mean gestation length. But short gestation was more common among younger women, particularly among those under 20. No significant association was detected, however, between short gestation and history of induced abortion when the Mantel-Haenszel χ^2 test was applied to 40 strata formed by maternal race, age, and parity ($\chi^2{}_1 = 0.97$, $P = 0.32$, relative risk = 0.94). Table 52 shows the comparison of the two samples in which parity of the control group was incremented by one. The result of the comparison of these data was not significantly different from the preceding one ($\chi^2{}_1 = 3.54$, $P = 0.06$, relative risk = 0.88), suggesting that increase in gravidity due to induced abortion is not of major importance in effecting shorter gestation. Table 53 shows the result of the logistic regression analysis on all the vital data. The effect of induced abortion was found to be nonsignificant, the estimated relative risk being 0.89 ($z = -1.85$, $P = 0.06$).

Table 54 presents the matched hospital data. The result of matched pair analysis is consistent with the above findings, again showing no significant association between short gestation and induced abortion ($\chi^2{}_1 \cong 0$, relative risk = 1.00). The result of analysis based on the multivariate logistic model applied to the hospital data is shown in Table 55. Filipino and Oriental women tend to have short gestations more frequently than Caucasian women. Again, allowance of all the covariates under the logistic model did not change the relationship of short gestation with history of induced abortion observed earlier ($\hat{\beta}_I = -0.084$, $z = -0.72$, $P = 0.47$, relative risk = 0.92).

In the foregoing analysis, we defined short gestation as gestation length less than 37 weeks. The problem of premature delivery can also be studied by examining mean gestation length in relation to history of induced abortion. This approach has an advantage in that the variable can be treated as a continuous one in a model of standard multiple regression. For this analysis, independent variables included were year, sex of baby, maternal age, marital status, mother's years of education, parity, number of previous fetal deaths, and maternal race, in addition to the variable representing induced abortion. Polynomial terms of year, age, education, parity, and previous fetal death were also included as independent variables in the model (Table 56). The effect of induced abortion was studied alternatively by the presence (1) or absence (0) of an abortion history or by number of previous induced abortions as an independent variable along with the other covariates mentioned above.

TABLE 52 Short gestation of subsequent pregnancies among abortion
(Parity 0 versus 1 and 1+ versus 2+ for abortion and control groups,

	Parity		Abortion group		
Age group	Abortion	Control	Short gest.	No short gest.	Total
<20	0	1	37	351	388
	1+	2+	6	39	45
20–24	0	1	75	824	899
	1+	2+	38	382	420
25–29	0	1	40	602	642
	1+	2+	47	445	492
>29	0	1	9	154	163
	1+	2+	35	336	371
Total			287	3,133	3,420

$\chi^2_1 = 3.54$.

$P = 0.06$.

Relative risk = 0.88.

Table 56 shows the partial regression coefficients and analysis of variance resulting from the regression analysis. All the independent variables, including history of induced abortion, except parity, were found to be significantly associated with gestation length. The statistical significance is not surprising in view of the extremely large sample size (N = 88,501). History of induced abortion was positively associated with gestation length ($F = 12.94$, $P < 0.001$). It is more meaningful, however, to examine the actual magnitude of the effect of induced abortion on gestation length. The partial regression coefficient (0.1816) indicates that women with a positive history of one or more induced abortions had on the average $7 \times 0.1816 = 1.27$ days longer gestation than women with no history of such events. If we express the effect in terms of number of induced abortions, the magnitude is even less, an average of $7 \times 0.0958 = 0.67$ day per induced abortion (Table 56). The practical significance of these effects is debatable.

Table 57 shows the comparisons of the abortion and control samples matched by outcome of previous pregnancy and parity. Although the numbers involved in these comparisons are somewhat limited, none of the comparisons showed a significant association between

and control groups, by age and parity
respectively)

		Control group				
Prop.	Mean	Short gest.	No short gest.	Total	Prop.	Mean
0.0954	39.758	224	1,408	1,632	0.1373	39.241
0.1333	38.667	55	181	236	0.2331	38.712
0.0834	39.808	625	6,947	7,572	0.0825	39.759
0.0905	39.776	299	2,635	2,934	0.1019	39.655
0.0623	39.835	478	6,783	7,261	0.0658	39.738
0.0955	39.648	526	5,614	6,140	0.0857	39.774
0.0552	39.656	323	3,320	3,643	0.0887	39.440
0.0943	39.563	764	7,187	7,951	0.0961	39.470
0.0839	39.732	3,294	34,075	37,369	0.0881	39.627

short gestation and induced abortion. But clear contrast can be noticed between the A1 versus P1 and A1 versus P0 comparisons. For gravida 2, the A1 groups had a higher rate of short gestation (0.0610) than the P1 group (0.0441), the relative risk being 1.38. The trend was reversed in the comparison of the A1 group (0.0385) with the P0 group (0.0680); relative risk was 0.57. The data suggest that nulliparous women with a history of single induced abortion are intermediate in their gestation length of subsequent pregnancy between nulliparous and primiparous women. Expressed in another way, a first induced abortion behaves as though it is half of a full-term pregnancy in its effect on gestation length of later pregnancy.

Table 58 shows the adjusted relative risks of short gestation in relation to factors associated with previous induced abortion. Among the six factors studied, only use of laminaria was associated significantly with the risk of short gestation in a subsequent pregnancy (χ^2_1 = 11.51, $P < 0.001$, relative risk = 0.46). Surprisingly, users of laminaria had a lower frequency of short gestation than others. A similar trend was also evident within the abortion cohort sample (χ^2_1 = 4.79, $P = 0.03$, relative risk = 1.30), as shown in Table 59.

TABLE 53 Estimated coefficients of multivariate logistic function and significance test for short gestation: all vital data

Variable	Coefficient	Standard error	z
Constant	-1.389		
Year of outcome	0.013	0.005	2.46*
Woman's age	-0.005	0.003	-1.83
Race			
Hawaiian or part-Hawaiian	0.472	0.036	13.16†
Filipino	0.624	0.037	16.99†
Oriental	0.278	0.034	8.11†
Other	0.582	0.049	11.83†
Resident island	-0.075	0.032	-2.35*
Pregnancy order	0.015	0.009	1.71
Current marital status	0.533	0.037	14.28†
Woman's education	-0.059	0.006	-10.29†
History of induced abortion	-0.117	0.063	-1.85

Relative risk = $e^{-0.117}$ = 0.89.

* Significant at 0.05 level.

† Significant at 0.001 level.

TABLE 54 Distribution of matched pairs, by combination of short gestation

	Control group		
Abortion group	Short gestation	No short gestation	Total
Short gestation	9	141	150
No short gestation	141	2,555	2,696
Total	150	2,696	2,846

NOTE: Frequency of short gestation for abortion group = 0.053. Frequency of short gestation for control group = 0.053. Relative risk = 1.00.

TABLE 55 Estimated coefficients of multivariate logistic function and significance test for short gestation

Variable	Coefficient	Standard error	*z*
Constant	-2.358		
Year of outcome	-0.038	0.042	-0.92
Woman's age	-0.043	0.015	-2.94*
Race			
Hawaiian or part-Hawaiian	0.305	0.163	1.87
Filipino	0.583	0.182	3.20*
Oriental	0.441	0.158	2.79*
Other	0.066	0.253	0.26
Resident island	-0.049	0.154	0.32
Pregnancy order	0.136	0.042	3.24*
Current marital status	0.265	0.166	1.59
History of induced abortion	-0.084	0.118	-0.72

Relative risk = $e^{-0.084}$ = 0.92.

* Significant at 0.01

In summary, our data provide no indication that the experience of prior induced abortion has any adverse effect on gestation length leading to a higher rate of premature delivery. This observation is in contrast to earlier observations reported from Japan (Moriyama and Hirokawa, 1966), Eastern Europe (Miltenyi, 1964; Dolezal et al., 1970; Atanasov et al., 1972), and Greece (Pantelakis et al., 1973; Papaevangelou et al., 1973). But our findings are consistent with more recent studies, conducted in the United States (Daling and Emanuel, 1977; Schoenbaum et al., 1980) and other parts of the world (Daling and Emanuel, 1975; WHO Task Force, 1979; Obel, 1979a), that had better control of confounding variables. Summarizing ten major studies in the world, Tietze (1981) has estimated the unweighted mean of relative risk as 1.05, which is generally consistent with our results. The range of our relative risk is 0.57 to 1.38, depending on type of comparison. Our estimates of relative risk based on the vital records, however, were close to unity (0.94 and 0.89), as shown earlier. The differences in these estimates appear to depend on adjustment for

TABLE 56 Regression analysis of gestation-length testing effects of history of induced abortion (IA) and number of previous abortions

Variable	History of induced abortion	Number of induced abortions
Year	0.1731†	0.1762†
(Year)^2	−0.0568††	−0.0573††
(Year)^3	0.0040††	0.0040††
Sex	−0.2085††	−0.2084††
Age	0.1837††	0.1842††
(Age)^2	−0.0036††	−0.0036††
Marital status	0.2426††	0.2421††
Education	0.0903††	0.0906††
(Education)^2	−0.0031††	−0.0031††
Parity	−0.0042	−0.0043
(Parity)^2	0.0006	0.0006
Previous fetal death	−0.0919††	−0.0873††
(Previous fetal death)^2	0.0075†	0.0071†
Woman's race		
Hawaiian	−0.4659††	−0.4644††
Filipino	−0.8479††	−0.8466††
Oriental	−0.4016††	−0.3991††
Other	−0.5771††	−0.5773††
History of IA	0.1816††	X
Number of previous IAs	X	0.0958*
R^2	0.0231	0.0230
SSq due to regression on covariates	16,409.83	16,409.83
d.f.	17	17
SSq due to IA variable after fitting the above	102.20	44.40
d.f.	1	1
SSq residual	698,953.31	699,011.11
d.f.	88,482	88,482
Residual MSq	7.90	7.90
F	12.94††	5.62*

* Significant at 0.05 level.

† Significant at 0.01 level.

†† Significant at 0.001 level.

X Not tested.

TABLE 57 Matched-pair comparisons of short gestation (SG) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
SG	1	1	18	13	17	30
No SG	34	34	277	282	424	411
Total	35	35	295	295	441	441
p	0.0285	0.0285	0.0610	0.0441	0.0385	0.0680
X^2_1	0.51		0.54		3.24	
RR	1.00		1.38		0.57	

reproductive history of the mothers. Tietze (1981) reported that when women who had had only one prior abortion were compared with women pregnant with parity 1 (gravida 2), the relative risks were higher for this group than for women with parity 0 (gravida 1). Our data are consistent with this observation, with risk estimates of 0.57 and 1.38 (Table 57). The same trend was demonstrated when we compared nulliparous women having a history of one or more abortions with women with parity 0 or parity 1 without consideration of gravidity. The respective relative risks estimated were 0.94 and 0.88 (Tables 51 and 52). It is important to point out that in nearly all of our comparisons, the estimated relative risks were less than unity, though nonsignificantly so, suggesting that if there were any effect of abortion, it tended to reduce rather than increase the risk of short gestation.

We are now faced with the problem of explaining the observation that use of laminaria was associated in our study with a lower incidence of premature delivery. The lower rate was associated generally with an increase of gestation length for laminaria users (Table 59). It is not clear how such a relationship can be explained biologically. We hypothesize that cervical injury caused by nonuse of laminaria somehow reduces the gestation length of subsequent pregnancy. This hypothesis is consistent with the observation (Obel, 1979b) that among women who had undergone abortion by means of suction, cervical dilatation of 12 mm. or less was accompanied by a lower incidence of short gestation than dilatation of 13 mm. or more, though the differ-

TABLE 58 Adjusted relative risks for short gestation associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
<20	0.86	0.66
20–24	0.90	0.41
25–29	1.18	0.47
>29	0.57	1.33
Number of IAs		
1	0.89	0.85
>1	1.00	0.01
Gestation weeks at last IA		
<9	0.77	2.34
9–12	0.95	0.08
>12	1.08	0.06
Procedure		
D&C	1.04	0.01
Suction	0.83	1.27
Saline	1.38	1.33
D&C + suction	0.82	1.23
Use of laminaria		
No	1.07	0.25
Yes	0.46	11.51*
Abortion complications		
No	0.92	0.46
Yes	0.75	0.54

* Significant at 0.001 level.

ence in the rates (7.3 versus 11.1 percent) was not significant. Further confirmation of the association is needed.

Low birth weight

In view of the observed racial variation in birth weight in Hawaii observed by Morton et al. (1967), it is neither realistic nor meaningful to use the usual criterion of 2,500 grams as a cutoff point for judging low birth weight, which is commonly used for Caucasian populations. Their study suggested that the equivalent birth weights should be

TABLE 59 Gestation length, by maternal age, parity, and use of laminaria at last induced abortion

	Laminaria				No laminaria			
Age group and parity	N	Short gest.	Prop. of short gest.	Mean gest.	N	Short gest.	Prop. of short gest.	Mean gest.
< 19								
0	135	11	0.081	40.26	259	27	0.104	39.47
1+	34	3	0.088	39.56	68	11	0.162	38.63
20–24								
0	319	20	0.063	39.87	627	56	0.089	39.71
1+	272	26	0.096	39.90	599	71	0.119	39.40
25–29								
0	193	12	0.062	40.02	484	30	0.062	39.74
1+	242	18	0.074	39.62	713	73	0.102	39.50
> 29								
0	50	2	0.040	40.10	135	7	0.052	39.61
1+	140	15	0.107	39.44	455	45	0.099	39.47
Total								
0	697	45	0.065	40.00	1,505	120	0.080	39.67
1+	688	62	0.090	39.69	1,835	200	0.109	39.43

$X^2_1 = 4.79$.

Significant at 0.03 level.

Relative risk = 1.30.

2,300 grams for Japanese and Chinese, and 2,200 grams for Filipinos. We therefore used the following criteria for deciding race-specific low birth weights in our study: 2,500 grams for Caucasians and Hawaiians or part-Hawaiians, 2,300 grams for Orientals, 2,200 grams for Filipinos, and 2,400 grams for other racial combinations. The last category is rather arbitrary but reasonable because the majority of "Other" subjects were interracial crosses involving Caucasians or Hawaiians. Thus, for a given racial group, any newborn weighing the race-specific number of grams or less was considered to have a low birth weight. As in the case of gestation length, the data included only single live births occurring after a gestation length of 20 weeks or longer.

Table 60 shows the proportions of low birth-weight infants and

TABLE 60 Low birth weight (LBW) associated with subsequent pregnancies of abortion and control groups, by age and parity
(Parity classified as 0 or 1+ for both groups)

Age group and parity	Abortion group					Control group				
	LBW	No LBW	Total	Prop.	Mean	LBW	No LBW	Total	Prop.	Mean
< 20										
0	26	362	388	0.0670	3185.4	959	11,730	12,689	0.0756	3166.7
1+	4	41	45	0.0889	3151.4	187	1,681	1,868	0.1001	3149.9
20–24										
0	45	854	899	0.0501	3217.6	1,067	18,606	19,673	0.0542	3230.7
1+	21	399	420	0.0500	3284.8	553	9,953	10,506	0.0526	3310.7
25–29										
0	23	619	642	0.0358	3306.1	511	11,313	11,824	0.0432	3220.3
1+	28	464	492	0.0569	3323.7	594	12,807	13,401	0.0443	3337.3
> 29										
0	6	157	163	0.0368	3210.8	268	3,799	4,067	0.0659	3159[illegible]
1+	9	362	371	0.0243	3425.2	584	11,010	11,594	0.0504	3316.3
Total	162	3,258	3,420	0.0474	3275.4	4,723	80,899	85,622	0.0552	3252.7

$\chi^2_1 = 2.38$.

$P = 0.12$.

Relative risk = 0.88.

mean birth weights for the abortion and control samples as stratified by maternal age and parity. Parity was classified by numbers 0 and 1 or more. In general, the abortion group tended to have a lower rate of low birth weight than the control group, though the difference was not significant ($\chi^2_1 = 2.38$, $P = 0.12$, estimated relative risk of 0.88). The respective overall frequencies of low birth weight were 4.74 and 5.52 percent. Table 61 presents a similar comparison, with nulliparous pregnancies excluded from the control group. The result is similar to that in Table 60, but the difference is barely significant ($\chi^2_1 = 4.05$, $P = 0.04$, estimated relative risk of 0.84). These results should be interpreted with extreme caution because many factors known to influence birth weight were not allowed for in these analyses. One of the more important factors is race of the child, which was not considered in these analyses. Morton et al. (1967) observed that birth weight is determined largely by child's race and there is no independent maternal effect in cases of interracial crosses. Furthermore, it is necessary to adjust for the effect of gestation length on birth weight to assess the net relationship between prior abortion and birth weight.

Table 62 shows the result of the logistic regression analysis of low birth weight on all the vital data. The independent variables include child's year of birth, mother's age, marital status, and education, pregnancy order, child's race, and gestation length. Child's race was coded to reflect the proportions of the given racial groups in outcrosses. The unknown racial category was created to take care of illegitimate births for which information on paternal race was missing. Despite uniformly significant associations of all of the covariates, reflecting the large sample size under the logistic model, it is indeed surprising that history of induced abortion remained nonsignificant in its relation to low birth weight ($\hat{\beta}_I = -0.078$, $z = -1.01$, $P = 0.31$). From the regression we estimated the relative risk for low birth weight to be 0.92. The result of the logistic regression analysis suggests that the Mantel-Haenszel χ^2 analysis is simply inadequate for studying birth weight because of its failure to account for numerous confounding variables.

Table 63 presents the analysis of the matched hospital data. The estimated relative risk of 1.14 was somewhat higher than the preceding ones but was not significantly different from unity ($\chi^2_1 = 0.91$, $P = 0.34$). The result of the logistic regression analysis is consistent with our earlier findings, the estimated relative risk being 0.97 ($\hat{\beta}_I = -0.030$, $z = -0.33$, $P = 0.74$), as shown in Table 64. Table 65 shows the result

TABLE 61 Low birth weight (LBW) associated with subsequent (Parity 0 versus 1 and 1+ versus 2+ for abortion and control,

	Parity		Abortion group		
Age group	Abortion	Control	LBW	No LBW	Total
< 20	0	1	26	362	388
	1+	2+	4	41	45
20–24	0	1	45	854	899
	1+	2+	21	399	420
25–29	0	1	23	619	642
	1+	2+	28	464	492
> 29	0	1	6	157	163
	1+	2+	9	362	371
Total			162	3,258	3,420

$\chi^2_1 = 4.05$.

Significant at 0.04 level.

Relative risk = 0.84.

of parity-matched comparisons for low birth weight. None of the differences between the abortion and control samples was significant when the A1 was contrasted to the S1, P0, and P1 groups, although the S1 comparison was limited by the small number of cases. However, it is noteworthy that the nulliparous control (P0) had a slightly higher rate of low birth weight than the abortion group (relative risk = 0.90), whereas the control group with parity 1 (P1) had a slightly lower risk of low birth weight than the abortion sample (relative risk = 1.08). This finding suggests that the pregnancy outcome of nulliparous women with a history of single induced abortion is intermediate between outcomes of nulliparous and parity 1 control women, as in the case of gestation length.

One could gain further insight into the relationship between prior induced abortion and birth weight of subsequent pregnancies by examining birth weight itself instead of low birth weight. The result of the regression analysis of birth weight is shown in Table 66, where birth weight is expressed in grams. The regression model replaced maternal race with race of the infant and included gestation length in addition to the same set of covariates considered earlier for the study of gestation length (Table 56). Interestingly, we found positive history

pregnancies of abortion and control groups, by age and parity
respectively)

		Control group				
Prop.	Mean	LBW	No LBW	Total	Prop.	Mean
0.0670	3185.4	153	1,479	1,632	0.0938	3155.6
0.0889	3151.4	34	202	236	0.1441	3110.5
0.0501	3217.6	374	7,198	7,572	0.0494	3320.6
0.0500	3284.8	179	2,755	2,934	0.0610	3285.1
0.0358	3306.1	280	6,981	7,261	0.0386	3324.0
0.0569	3323.7	314	5,826	6,140	0.0511	3352.9
0.0368	3210.8	192	3,451	3,643	0.0527	3278.1
0.0243	3425.2	392	7,559	7,951	0.0493	3333.8
0.0474	3275.4	1,918	35,451	37,369	0.0513	3313.9

of induced abortion to be associated significantly with higher birth weight ($F_{1,\,88481} = 28.65$, $P < 0.001$), although the magnitude is relatively small: 46.43 grams higher for those with one or more prior induced abortions. When we examined the effect of number of previous induced abortions, the increase was 38.34 grams per abortion. These results are consistent with the earlier observation of a lower rate of low birth weight for abortion subjects of a given parity (Table 65). Stated in another way, there is generally a slight increase of birth weight for subsequent births of the abortion women; the increase could be attributed to an additional gravidity for that group, which was not allowed for in the regression analysis. We could judge the effect of an induced abortion in relation to the effect of a unit increment in parity from 0 to 1. From the partial regression coefficients, we estimate the increase to be $46.62 - 2.38 = 44.24$ grams per parity, which should be contrasted to an average increase of 38.34 grams per abortion. On the basis of this evidence, it could be concluded that an artificially terminated pregnancy has an increasing effect on the birth weight of the baby of a subsequent pregnancy, but the magnitude of the increase is less (though not much less) than the effect of parity as characterized by a full-term delivery.

TABLE 62 Estimated coefficients of multivariate logistic function and significance test for low birth weight: all vital data

Variable	Coefficient	Standard error	z
Constant	25.174		
Year of outcome	-0.039	0.007	-6.05††
Woman's age	-0.010	0.003	-2.90†
Child's race			
Hawaiian or part-Hawaiian	0.120	0.027	4.46††
Filipino	-0.431	0.026	-16.89††
Oriental	-0.295	0.024	-12.48††
Other	-0.320	0.033	-9.66††
Unknown	-0.192	0.080	-2.41*
Pregnancy order	-0.027	0.011	-2.56*
Current marital status	0.350	0.060	5.87††
Woman's education	-0.028	0.007	-3.93††
Gestation length	-0.712	0.006	-124.96††
History of induced abortion	-0.078	0.077	-1.01

Relative risk = $e^{-0.078}$ = 0.92.

* Significant at 0.05 level.

† Significant at 0.01 level.

†† Significant at 0.001 level.

TABLE 63 Distribution of matched pairs, by combination of low birth weight (LBW)

	Control group		
Abortion group	LBW	No LBW	Total
LBW	6	132	138
No LBW	116	2,371	2,487
Total	122	2,503	2,625

Frequency of LBW for abortion group = 0.053.

Frequency of LBW for control group = 0.046.

Relative risk = 1.14.

TABLE 64 Estimated coefficients of multivariate logistic function and significance test for low birth weight: hospital data

Variable	Coefficient	Standard error	z
Constant	32.740		
Year of outcome	-0.037	0.033	-1.13
Woman's age	-0.019	0.011	-1.62
Race			
Hawaiian or part-Hawaiian	-0.117	0.128	-0.92
Filipino	-0.476	0.143	-3.33†
Oriental	-0.723	0.124	-5.83†
Other	-0.132	0.198	-0.67
Resident island	-0.562	0.120	-4.67†
Pregnancy order	0.045	0.032	1.36
Current marital status	0.289	0.130	2.22*
Gestation length	-0.880	0.025	-35.40†
History of induced abortion	-0.030	0.092	-0.33

Relative risk = $e^{-0.030}$ = 0.97.

* Significant at 0.05 level.

† Significant at 0.01 level.

TABLE 65 Matched-pair comparisons of low birth weight (LBW) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
LBW	4	1	13	12	18	20
No LBW	28	31	253	254	390	388
Total	32	32	266	266	408	408
p	0.1250	0.0313	0.0489	0.0451	0.0441	0.0490
X^2_1	0.87		0		0.03	
RR	4.00		1.08		0.90	

TABLE 66 Regression analysis of birth-weight testing effects of history of induced abortion (IA) or number of previous induced abortions

Variable	History of induced abortion	Number of induced abortions
Year	16.4305	16.8029
(Year)^2	-1.1322	-1.2179
(Year)^3	0.0250	0.0303
Sex	112.9292††	112.9457††
Age	11.7293††	11.6933††
(Age)^2	-0.1661††	-0.1655††
Marital status	84.4725††	84.6249††
Education	-5.0233	-5.0566
(Education)^2	0.4324†	0.4344†
Parity	46.6296††	46.6216††
(Parity)^2	-2.3856††	-2.3846††
Previous fetal death	-21.9420††	-22.2685††
(Previous fetal death)^2	1.1285*	1.1369
Baby's race		
Hawaiian	-91.2611††	-91.1753††
Filipino	-278.6780††	-278.6853††
Oriental	-231.4633††	-231.4630††
Other	1.2604	1.2572
Gestation	81.5447††	81.5567††
History of IA	46.4288††	X
Number of previous IAs	X	38.3441††
R^2	0.2412	0.2412
SSq due to regression on covariates	$6,532.18 \times 10^6$	$6,532.18 \times 10^6$
d.f.	18	18
SSq due to IA variable after fitting the above	6.6598×10^6	7.0950×10^6
d.f.	1	1
SSq residual	$20,567.28 \times 10^6$	$20,566.85 \times 10^6$
d.f.	88,481	88,481
Residual MSq	0.2324	0.2324
F	28.65††	30.53††

* Significant at 0.05 level; † Significant at 0.01 level; †† Significant at 0.001 level;
X Not tested.

The data from the regression analysis can also be used to predict the rate of low birth weight for the abortion group. The mean and the standard deviation of the entire control sample were 3,253 and 533.4 grams, respectively. Given the weighted mean of the race-specific prematurity criterion as 2,405 grams, we can predict the frequency of low birth weight as 0.0559 from a table of cumulative normal distribution, assuming that birth weight is normally distributed. When the mean of birth weight is displaced by 38.34 grams because of a prior induced abortion, the predicted frequency of low birth weight is 0.0475. These predictions are nearly identical to what we observed, 0.0552 and 0.0474 (Table 60). The corresponding relative risk is 0.85, compared with the earlier estimate of 0.88. This observation strengthens our earlier conclusion that the observed slightly lower frequency of low birth weight for the abortion sample can be attributed to the slight increase of mean birth weight for the group.

Table 67 shows the result of tests of possible association between factors associated with abortion procedure and low birth weight. None of the factors studied was found to be significantly related to the risk of low birth weight. This is not surprising in light of the negative association between abortion and low birth weight described above. The relative risk for the D&C procedure was higher than that of other factors (value of 1.36) but was not significantly different from unity.

Our findings on birth weight as a sequela variable of induced abortion are consistent with the results of other recent studies (Hogue, 1975; Daling and Emanuel, 1975; Daling and Emanuel, 1977; WHO Task Force, 1979; Obel, 1979a; Schoenbaum et al., 1980) in which confounding variables are better controlled. In summarizing various major studies, Tietze (1981) estimated the overall relative risk of low birth weight as 1.08, which is compatible with our estimates of relative risk. He also noted that there was a general tendency for the relative risk to increase as parity of the control group was changed from 0 to 1. Our data are again in agreement with that trend (Table 65). Thus it must be concluded that the experience of induced abortion in itself does not seem to have an adverse effect on the birth weight of subsequent delivery. Whatever effect is observed can be attributed to the biological effect of the prior pregnancy itself, which happened to result in artificial termination.

Two reports claim to find an association between abortion procedure and the risk of low birth weight. The WHO study (1979) found

TABLE 67 Adjusted relative risks for low birth weight associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
< 20	1.04	0.07
20–24	0.99	~0
25–29	1.01	~0
> 29	0.92	0.02
Number of IAs		
1	1.03	0.05
> 1	0.86	0.38
Gestation weeks at last IA		
< 9	0.82	2.15
9–12	1.09	0.46
> 12	1.27	1.87
Procedure		
D&C	1.36	3.78
Suction	0.94	0.21
Saline	1.30	1.14
D&C + suction	0.85	1.15
Use of laminaria		
No	1.05	0.16
Yes	0.88	0.56
Abortion complications		
No	1.01	~0
Yes	1.02	~0

higher risk associated with the D&C procedure, whereas Obel (1979b) observed an increased risk of low birth weight for deliveries preceded by cervical dilatation of 13 mm. or more for the suction procedure. We calculated the relative risk to be 1.36 for the D&C procedure, which was not significant. Furthermore, it should be pointed out that significant association was found in only one of three city clusters studied by the WHO group, thus indicating an inconsistency. The observed association between degree of cervical canal dilatation and risk of low birth weight could be due to premature delivery, which was also affected (Obel, 1979b). If this hypothesis is confirmed, a good biological explanation for the phenomenon must be sought.

Pregnancy complications

In the vital records, pregnancy complications were rather loosely defined. For the period of 1968 through 1977, pregnancy complications included amnionitis, anemia, eclampsia, hyperemesis gravidarum, pre-eclampsia, premature rupture of membranes, pyelitis, Rh sensitization, toxemia, and other unspecified conditions. Beginning in 1978, placental abnormalities, renal disease, and edema replaced amnionitis, pyelitis, and toxemia, respectively, and urinary infection was added. For the purpose of overall analysis of these vital data, we recoded the information into the binary form as the presence (1) or absence (0) of one or more of these conditions.

Table 68 shows the rates of pregnancy complications of the abortion and control samples from the vital records, by age and parity. The overall frequencies of complications were similar, 0.0650 and 0.0629 for the abortion and control groups, respectively. The data show no significant association between previous abortion and pregnancy complication rates; the estimated relative risk was 1.10 ($\chi^2_1 = 1.74, P = 0.19$). But the situation was drastically altered when we contrasted the abortion sample with the control by incrementing parity for the control sample by one (Table 69). The abortion sample had consistently higher rates of complication than the control sample (overall rate of 0.0650 versus 0.0481). The association appears unquestionable, with a χ^2 value of 41.82 ($P \cong 0$) and a relative risk of 1.64. These observations strongly suggest that pregnancies of women with a history of single induced abortion behave much like nulliparous pregnancies not preceded by abortion.

The result of the logistic regression analysis further supports this conclusion (Table 70). Pregnancy order, which is largely determined by parity in these data, is clearly shown to be negatively associated with the risk of pregnancy complications; the higher the pregnancy order, the lower the risk. Other significant variables were year, maternal age, race, and mother's education. When all of these and other covariates were allowed for, the effect of induced abortion was not significant ($\hat{\beta}_I = 0.099, z = 1.32, P = 0.19$) and the relative risk (1.10) was identical to the first estimate shown above.

The hospital data on pregnancy complications were more extensive than those reported in birth certificates of the State Health Department. In addition to those recorded in the vital records, we included the following conditions as ascertained from hospital records: isolated

TABLE 68 Pregnancy complications of subsequent pregnancies of abortion and control groups, by age and parity
(Parity classified as 0 or 1+ for both groups)

	Abortion group				Control group			
Age group and parity	Complications	No complications	Total	Prop.	Complications	No complications	Total	Prop.
< 20								
0	22	364	386	0.0570	897	11,546	12,443	0.0721
1+	0	45	45	0	76	1,760	1,836	0.0414
20–24								
0	61	831	892	0.0684	1,442	17,986	19,428	0.0742
1+	21	391	412	0.0510	425	9,926	10,351	0.0411
25–29								
0	45	580	625	0.0720	801	10,824	11,625	0.0689
1+	29	459	488	0.0594	600	12,623	13,223	0.0454
> 29								
0	17	141	158	0.1076	389	3,587	3,976	0.0978
1+	24	341	365	0.0658	670	10,731	11,401	0.0588
Total	219	3,152	3,371	0.0650	5,300	78,983	84,283	0.0629

$\chi^2_1 = 1.74$.
$P = 0.19$.
Relative risk = 1.10.

occurrence of proteinuria or hypertension, abnormalities of amniotic fluid, vascular disorders, and gestational diabetes.

Table 71 shows the hospital data on 3,416 matched pairs. The overall rates of pregnancy-related complications derived from the hospital data were higher than those from the vital records, as expected; in fact, they were approximately twice those of the vital data. But no significant association could be detected between abortion history and pregnancy complications in subsequent pregnancies ($\chi^2_1 = 0.90$, $P = 0.34$). The estimated relative risk of 0.93 was consistent with the earlier observations. This finding is further corroborated by the result of the logistic regression analysis in Table 72, which indicates a relative risk of 0.95 and hence not a significant deviation from unity ($\hat{\beta}_I = -0.048$, $z = -1.63$, $P = 0.10$).

TABLE 69 Pregnancy complications of subsequent pregnancies of abortion and control groups, by age and parity

(Parity 0 versus 1 and 1+ versus 2+ for abortion and control, respectively)

Age group	Parity		Abortion group				Control group			
	Abortion	Control	Complications	No complications	Total	Prop.	Complications	No complications	Total	Prop.
< 20	0	1	22	364	386	0.0570	61	1,543	1,604	0.0380
	1+	2+	0	45	45	0	15	217	232	0.0647
20–24	0	1	61	831	892	0.0684	317	7,165	7,482	0.0424
	1+	2+	21	391	412	0.0510	108	2,761	2,869	0.0376
25–29	0	1	45	580	625	0.0720	351	6,845	7,196	0.0488
	1+	2+	29	459	488	0.0594	249	5,778	6,027	0.0413
> 29	0	1	17	141	158	0.1076	212	3,376	3,588	0.0591
	1+	2+	24	341	365	0.0658	458	7,355	7,813	0.0586
Total			219	3,152	3,371	0.0650	1,771	35,040	36,811	0.0481

$\chi^2_1 = 41.82$.

$P \cong 0$.

Relative risk = 1.64.

TABLE 70 Estimated coefficients of multivariate logistic function and significance test for pregnancy complications: all vital data

Variable	Coefficient	Standard error	z
Constant	-2.890		
Year of outcome	0.028	0.006	4.29†
Woman's age	0.021	0.003	6.67†
Race			
Hawaiian or part-Hawaiian	-0.211	0.042	-4.97†
Filipino	-0.394	0.043	-9.08†
Oriental	-0.655	0.041	-16.11†
Other	-0.208	0.058	-3.57†
Resident island	-0.009	0.038	-2.35
Pregnancy order	-0.096	0.010	-9.42†
Current marital status	-0.084	0.044	-1.90
Woman's education	-0.022	0.007	-3.19*
History of induced abortion	0.099	0.075	1.32

Relative risk = $e^{0.096}$ = 1.10.

* Significant at 0.01 level.

† Significant at 0.001 level.

TABLE 71 Distribution of matched pairs, by presence or absence of pregnancy complications

	Control group		
Abortion group	Complications	No complications	Total
Complications	59	364	423
No complications	391	2,602	2,993
Total	450	2,966	3,416

Frequency of complications for abortion group = 0.1238.

Frequency of complications for control group = 0.1317.

Relative risk = 0.93.

TABLE 72 Estimated coefficients of multivariate logistic function and significance test for pregnancy complications: hospital data

Variable	Coefficient	Standard error	z
Constant	-10.319		
Year of outcome	0.111	0.027	4.15*
Woman's age	0.009	0.009	0.97
Race			
Hawaiian or part-Hawaiian	-0.512	0.105	-4.86*
Filipino	-0.391	0.117	-3.35*
Oriental	-0.527	0.102	-5.17*
Other	-0.259	0.163	-1.59
Resident island	0.445	0.099	4.49*
Pregnancy order	-0.021	0.027	-0.77
Current marital status	-0.118	0.104	-1.14
History of induced abortion	-0.048	0.076	-1.63

Relative risk = $e^{-0.048}$ = 0.95.

* Significant at 0.01 level.

Table 73 presents the parity matched hospital data. Although none of the comparisons showed significant differences, there was a clear tendency for differences associated with parity of the control samples to confirm the earlier observations. The pregnancies of women whose only prior pregnancy was terminated by induced abortion (A1) tended to have a slightly lower rate of complications than those of the nulliparous control group (P0), whereas the reverse was true in relation to the P1 control group (relative risk = 1.33). There were too few observations in the spontaneous-abortion control group (S1) for a reliable comparison.

Table 74 shows specific pregnancy complications for the 3,416 pairs of pregnancies derived from hospital records. Nearly all types of complication were evenly distributed between the two groups. The only significant difference was observed for hyperemesis, as tested by χ^2 on the assumption that the data were unmatched ($\chi^2_1 = 9.55$, $P = 0.002$, relative risk estimated at 3.24). The significance of this finding is not clear if it does not represent a chance relationship. Using

TABLE 73 Matched-pair comparisons of pregnancy complications (PC) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
PC	6	10	35	27	71	93
No PC	34	30	298	306	463	441
Total	40	40	333	333	534	534
p	0.1500	0.2500	0.1051	0.0811	0.1330	0.1742
X^2_1	0.70		0.87		3.18	
RR	0.50		1.33		0.72	

TABLE 74 Number of specific pregnancy complications, by abortion and control samples: matched hospital data

Complication	Abortion	Control
None	2,994	2,966
Amnionitis	19	15
Anemia	34	37
Eclampsia	3	1
Hyperemesis	29	9
Pre-eclampsia	97	112
Premature rupture of membranes	190	209
Renal disease	4	1
Hemolytic disease	18	20
Edema	9	7
Proteinuria	2	1
Hypertension	13	24
Abnormalities of amniotic fluid	1	7
Vascular disorders	4	3
Gestational diabetes	44	53
Other	5	2

the hospital data and log-linear analysis, Kong (1981) examined factors specifically affecting pre-eclampsia. The factors studied were maternal age, parity, number of prenatal visits, month of first prenatal visit, and history of induced abortion. The analysis detected no significant association, thus confirming the present finding.

Table 75 shows adjusted relative risks for factors associated with abortion procedure based on the method of multivariate confounder scores. The only significant association was found with the D&C + suction procedure. But the relative risk estimate (0.76) was in the

TABLE 75 Adjusted relative risks of pregnancy complications associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
<20	1.04	0.11
20–24	0.86	2.17
25–29	0.95	0.10
>29	1.10	0.16
Number of IAs		
1	0.96	0.31
>1	0.91	0.26
Gestation weeks at last IA		
<9	0.91	0.77
9–12	0.97	0.11
>12	1.02	0.005
Procedure		
D&C	1.32	3.65
Suction	1.00	0.001
Saline	1.12	0.28
D&C + suction	0.76	6.18*
Use of laminaria		
No	0.95	0.36
Yes	0.95	0.14
Abortion complications		
No	0.92	1.16
Yes	1.31	0.20

* Significant at 0.01 level.

TABLE 76 Pregnancy complications (PC) of subsequent pregnancies, by use of laminaria, abortion procedure, and parity

Procedure	Laminaria				No laminaria			
and parity	PC	No PC	Total	Prop.	PC	No PC	Total	Prop.
D&C								
0	2	32	34	0.0588	31	237	268	0.1157
1+	0	30	30	0	26	312	338	0.0769
Suction								
0	18	282	300	0.0600	43	540	583	0.0738
1+	8	280	288	0.0278	31	673	704	0.0440
D&C + suction								
0	16	273	289	0.0554	36	487	523	0.0688
1+	10	246	256	0.0391	40	636	676	0.0592
Other								
0	5	63	68	0.0735	12	161	173	0.0694
1+	6	78	84	0.0714	8	135	143	0.0559
Total	65	1,284	1,349	0.0482	227	3,181	3,408	0.0666

$\chi^2_1 = 4.09$.

Significant at 0.04 level.

Relative risk = 0.73.

direction opposite from that to be expected if the procedure had a harmful effect. When we classified the data simply by procedure and parity within the abortion cohort, we could detect no difference between suction (0.0533) and D&C + suction (0.0585), though the D&C procedure led to a higher incidence of pregnancy complications (0.0881). Table 76 shows that the use of laminaria at previous induced abortion produced a significantly lower rate of complications within the abortion sample ($\chi^2_1 = 4.09$, $P = 0.04$, relative risk of 0.73) than nonuse of laminaria.

Some previous studies reported a higher incidence of bleeding in the early stage of subsequent pregnancies of women with a history of induced abortion (Dziewulska, 1973; Harlap and Davies, 1975; Atanasov et al., 1972; Obel, 1979a), but Furusawa and Koya (1966) reported no such association. Unfortunately, our data contained no specific information on bleeding, but they were consistent with the conclusion reached by Schoenbaum et al. (1980) that women of second gravida with a history of single induced abortion are like nulliparous women with no such history of some types of complications.

Labor complications

For the period 1968–77, labor complications included the following specific conditions in addition to the "other" category in the vital records: placenta previa, abruptio placenta, other hemorrhage, prolapse of cords, breech presentation, other malpresentation, prolonged labor, and precipitate labor. Added in 1978 were three more specific conditions: fetopelvic disproportion, abnormality of pelvis, and multiple pregnancy. As in the case of pregnancy complications, we recoded labor complications into the binary form as presence (1) or absence (0) of one or more of these conditions for our analysis.

Table 77 shows the rates of labor complications for the abortion and control groups as stratified by maternal age and parity. The difference in labor complications between the abortion and control groups (11.96 and 11.00 percent, respectively) was slight, barely reaching a level of significance ($\chi^2_1 = 4.06$, $P = 0.04$, relative risk = 1.12). But the higher risk of labor complications for the abortion group proved to be unquestionable when parity was increased by 1 for the control group in the comparison (Table 78). In that case $\chi^2_1 = 111.18$, $P \cong 0$, and the estimated relative risk was 1.86. That the difference was largely limited to the comparison of nulliparous abortion women with primiparous control women indicates that it was due to parity between the two groups. This conclusion is further supported by the results of multivariate logistic regression analysis, in which the effects of pregnancy order as well as other factors were taken into account (Table 79). The regression analysis showed history of induced abortion to be nonsignificant (relative risk of 1.09).

The matched hospital data included additional labor complications: lacerations, retention of placenta, incompetent cervix, and C-sections (Table 80). Because of the expanded definition of complications, the overall rate of complications in the hospital data was approximately double that of the earlier estimate from the vital data. Even with the expanded definition of labor complications, however, no significant association was detected between abortion history and complications ($\chi^2_1 = 3.15$, $P = 0.08$), the relative risk of 0.90 being consistent with the preceding finding. Essentially, the same picture emerges from the

TABLE 77 Labor complications of subsequent pregnancies of abortion and control groups, by age and parity
(Parity classified as 0 or 1+ for both groups)

	Abortion group				Control group			
Age group and parity	Complications	No complications	Total	Prop.	Complications	No complications	Total	Prop.
< 20								
0	44	340	384	0.1146	1,301	10,959	12,260	0.1061
1+	3	42	45	0.0667	118	1,690	1,808	0.0653
20–24								
0	118	761	879	0.1342	2,516	16,558	19,074	0.1319
1+	33	380	413	0.0799	684	9,527	10,211	0.0670
25–29								
0	97	511	608	0.1595	1,693	9,685	11,378	0.1488
1+	34	449	483	0.0704	965	12,085	13,050	0.0739
> 29								
0	25	128	153	0.1634	780	3,089	3,869	0.2016
1+	44	318	362	0.1215	1,059	10,162	11,221	0.0944
Total	398	2,929	3,327	0.1196	9,116	73,755	82,871	0.1100

$X^2_1 = 4.06$.
Significant at 0.04 level.
Relative risk = 1.12.

multivariate logistic regression analysis, which yielded a nonsignificant relative risk of 0.96 (Table 81). Parity-specific comparisons of the matched data are shown in Table 82. Although none of the estimates of relative risk was significant, the parity effect observed in the earlier results from the vital data persisted in these data.

Table 83 shows the distribution of specific types of labor complications for the two groups, unadjusted for parity. Nearly all of the conditions were evenly distributed between the two groups. There were more cases of "other" lacerations among the control group than among the abortion group ($\chi^2_1 = 16.82$, $P \cong 0$), but the importance of this heterogeneous entity is questionable. Interpretation of other apparent differences between the abortion and control cohorts is difficult in the absence of allowance for parity effects. Using a log-linear

TABLE 78 Labor complications of subsequent pregnancies of abortion and control groups by age and parity
(Parity 0 versus 1 and 1+ versus 2+ for abortion and control, respectively)

	Parity		Abortion group				Control group			
Age group	Abor- tion	Con- trol	Compli- cations	No compli- cations	Total	Prop.	Compli- cations	No compli- cations	Total	Prop.
< 20	0	1	43	340	384	0.1146	102	1,476	1,578	0.0646
	1+	2+	3	42	45	0.0667	16	214	230	0.0696
20–24	0	1	118	761	879	0.1342	505	6,870	7,375	0.0685
	1+	2+	33	380	413	0.0799	179	2,657	2,836	0.0631
25–29	0	1	97	511	608	0.1595	561	6,516	7,077	0.0793
	1+	2+	34	449	483	0.0704	404	5,569	5,973	0.0676
> 29	0	1	25	128	153	0.1634	323	3,195	3,518	0.0918
	1+	2+	44	318	362	0.1215	736	6,967	7,703	0.0955
Total			398	2,929	3,327	0.1196	2,826	33,464	36,290	0.0779

$\chi^2_1 = 111.18$.

$P \cong 0$.

Relative risk = 1.86.

TABLE 79 Estimated coefficients of multivariate logistic function and significance test for labor complications: all vital data

Variable	Coefficient	Standard error	z
Constant	-3.052		
Year of outcome	0.050	0.005	10.26*
Woman's age	0.029	0.002	11.96*
Race			
Hawaiian or part-Hawaiian	-0.154	0.032	-4.76*
Filipino	0.0001	0.033	0.004
Oriental	-0.324	0.031	-10.48*
Other	0.044	0.044	1.00
Resident island	0.037	0.029	1.28
Pregnancy order	-0.137	0.008	-17.71*
Current marital status	-0.217	0.034	-6.48*
Woman's education	-0.001	0.005	-0.26
History of induced abortion	0.089	0.057	1.56

Relative risk = $e^{0.089}$ = 1.09.

* Significant at 0.001 level.

TABLE 80 Distribution of matched pairs, by labor complications

	Control group		
Abortion group	Complications	No complications	Total
Complications	189	578	767
No complications	641	2,008	2,649
Total	830	2,586	3,416

Frequency of complications for abortion group = 0.2245.

Frequency of complications for control group = 0.2430.

Relative risk = 0.90.

TABLE 81 Estimated coefficients of multivariate logistic function and significance test for labor complications: hospital data

Variable	Coefficient	Standard error	z
Constant	-4.611		
Year of outcome	0.042	0.021	1.99*
Woman's age	0.024	0.007	3.24†
Race			
Hawaiian or part-Hawaiian	-0.116	0.083	-1.40
Filipino	0.016	0.092	0.17
Oriental	-0.258	0.080	-3.22†
Other	0.105	0.128	0.82
Resident island	0.033	0.078	0.42
Pregnancy order	-0.058	0.021	-2.73†
Current marital status	-0.205	0.082	-2.49
History of induced abortion	-0.038	0.060	-0.63

Relative risk = $e^{-0.038}$ = 0.96.

* Significant at 0.05 level.

† Significant at 0.01 level.

TABLE 82 Matched-pair comparisons of labor complications (LC) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
LC	12	12	75	70	116	130
No LC	28	28	258	263	418	404
Total	40	40	333	333	534	534
p	0.3000	0.3000	0.2252	0.2102	0.2172	0.2434
X^2_1	0.06		0.14		0.89	
RR	1.00		1.09		0.87	

TABLE 83 Number of specific labor complications, by abortion and control groups: matched hospital data

Complication	Abortion	Control
None	2,385	2,249
Placenta previa	16	18
Abruptio placenta	40	31
Antepartum hemorrhage	9	8
Cord abnormalities	22	23
Breech presentation	103	90
Other malpresentation	7	15
Prolonged labor	58	79
Precipitate labor	60	92
Uterine inertia, etc.	148	161
Cephalopelvic disproportion	95	93
Premature labor	104	90
Rupture of uterus	2	1
Cervical laceration	38	33
Other lacerations	337	446
Retention of placenta	48	74
Incompetent cervix	9	11
Primary C-section	219	208
Repeat C-section	87	109

model, Kong (1981) studied the effects of a number of factors specifically on premature labor, including history of induced abortion. She found no significant independent effect of previous abortion on the risk of the condition.

Table 84 shows the adjusted relative risks for factors associated with previous induced abortion. None of the factors studied was a source of significantly elevated relative risks.

In summary, our study has demonstrated no clear-cut association of prior induced abortion with the risk of labor complications in subsequent pregnancies, when the parity effect was properly allowed for. Thus our finding is generally in accord with those of earlier studies in Japan (Furusawa and Koya, 1966) and the United States (Obel,

TABLE 84 Adjusted relative risks of labor complications associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
<20	0.98	0.05
20–24	0.95	0.47
25–29	0.96	0.10
>29	0.88	0.51
Number of IAs		
1	0.96	0.41
>1	0.94	0.18
Gestation weeks at last IA		
<9	0.96	0.20
9–12	0.87	3.13
>12	1.23	3.16
Procedure		
D&C	0.97	0.50
Suction	0.95	0.37
Saline	1.12	0.52
D&C + suction	0.90	1.41
Use of laminaria		
No	0.94	0.80
Yes	1.00	0.001
Abortion complications		
No	0.94	0.94
Yes	1.16	0.80

1979a; Schoenbaum et al., 1980), although all of the earlier studies concentrated on specific types of complications. Furusawa and Koya (1966) studied bleeding, length of labor, and use of instrumental delivery. Obel (1979a) examined the incidence of retained placenta or placental tissue, whereas Schoenbaum et al. (1980) investigated premature labor and placenta previa (or abruptio placenta). Our data do not support the finding of Slunsky (1964), who claimed an increased risk of premature labor associated with previous induced abortion. Clow and Crompton (1973) reported an increase of uterine rupture among women with a history of abortion, but our data provide little information on this point. We observed two cases of uterine rupture in the abortion group and one such case in the control group (Table 83).

Congenital malformations

It is well recognized that studies of congenital malformations tend to be constrained by incomplete ascertainment of cases and inaccurate diagnosis of specific malformations. Incidence estimates of major malformations vary with sources of case ascertainment. They range from 1–2 percent to 8 percent, depending on the study design (Chung and Myrianthopoulos, 1975). One important factor in ascertainment is time of diagnosis. Diagnosis generally improves with age of the infant (Myrianthopoulos and Chung, 1974). This study is confined to types of malformations detected at the time of birth through either the vital record system or hospital records. For that reason the degree of case ascertainment is expected to be incomplete. Incomplete ascertainment would not invalidate tests of the effect of abortion, however, since no difference in ascertainment is expected between the abortion and control groups.

The records obtained from the State Health Department followed three coding systems through the years. Depending on the year, the Department used its own codes specifying certain major malformations plus an unspecified category, ICDA codes, and a binary code assigning 1 to the presence and 0 to the absence of any malformation. For consistency, we recoded all the vital data uniformly into the binary format.

Table 85 shows the distribution of malformations for the abortion and control groups by maternal age and parity. The data included only live births following gestation of 20 weeks or longer, excluding multiple births. The overall incidence was about 1 percent, indicating a general underascertainment of cases. Morton et al. (1967) showed that ascertainment only by birth certificate underestimates the true population incidence. The Mantel-Haenszel χ^2 test showed no significant association between risk of malformation and history of induced abortion ($\chi^2_1 = 0.08$, $P = 0.78$, relative risk = 0.94). The result remained essentially unchanged when parity of the abortion group was matched with the control group at one higher parity ($\chi^2_1 = 0.06$, $P = 0.81$, relative risk = 0.94), as shown in Table 86. Allowance of

TABLE 85 Congenital malformations of subsequent pregnancies of abortion and control groups, by age and parity
(Parity classified as 0 or 1+ for both groups)

Age group and parity	Abortion group				Control group			
	Malf.	No malf.	Total	Prop.	Malf.	No malf.	Total	Prop.
< 20								
0	4	384	388	0.0103	127	12,562	12,689	0.0100
1+	0	45	45	0	29	1,839	1,868	0.0155
20–24								
0	8	891	899	0.0089	191	19,482	19,673	0.0097
1+	2	418	420	0.0048	118	10,371	10,489	0.0112
25–29								
0	6	636	642	0.0093	133	11,691	11,824	0.0112
1+	8	484	492	0.0163	125	13,223	13,348	0.0094
> 29								
0	1	162	163	0.0061	62	4,005	4,067	0.0152
1+	6	365	371	0.0162	133	11,414	11,547	0.0115
Total	35	3,385	3,420	0.0102	918	84,587	85,505	0.0107

$\chi^2_1 = 0.08$.
$P = 0.78$.
Relative risk = 0.94.

additional covariates by the logistic regression method yielded a nonsignificant relative risk of 0.98 (Table 87).

Table 88 shows the result of analyzing the matched hospital data. As expected, the overall incidence of congenital malformations ascertained in the hospitals was about 2 percent of all live births, double that obtained from birth certificates alone. Nevertheless, the risk of malformation remained independent of maternal history of induced abortion ($\chi^2_1 = 0.44$, $P = 0.51$, estimated relative risk = 1.13). This finding was further supported by the result of the multivariate logistic regression analysis (Table 89), which yielded a relative risk estimate of 1.12 ($z = 0.65$, $P = 0.52$). Parity-matched comparisons were less informative because of limited numbers of observed malformations

TABLE 86 Congenital malformations of subsequent pregnancies of abortion and control groups, by age and parity
(Parity 0 versus 1 and 1+ versus 2+ for abortion and control, respectively)

	Parity		Abortion group				Control group			
Age group	Abor-tion	Con-trol	Malf.	No malf.	Total	Prop.	Malf.	No malf.	Total	Prop.
< 20	0	1	4	384	388	0.0103	24	1,608	1,632	0.0147
	1+	2+	0	45	45	0	5	231	236	0.0212
20–24	0	1	8	891	899	0.0089	78	7,494	7,572	0.0103
	1+	2+	2	418	420	0.0048	40	2,877	2,917	0.0137
25–29	0	1	6	636	642	0.0093	64	7,197	7,261	0.0088
	1+	2+	8	484	492	0.0163	61	6,026	6,087	0.0100
> 29	0	1	1	162	163	0.0061	33	3,610	3,643	0.0091
	1+	2+	6	365	371	0.0162	100	7,804	7,904	0.0127
Total			35	3,385	3,420	0.0102	405	36,847	37,252	0.0109

$\chi^2_1 = 0.06$.

$P = 0.81$.

Relative risk = 0.94.

TABLE 87 Estimated coefficients of multivariate logistic function and significance test for congenital malformations: all vital data

Variable	Coefficient	Standard error	z
Constant	-4.362		
Year of outcome	-0.049	0.015	-3.30†
Woman's age	0.025	0.007	3.31††
Race			
Hawaiian or part-Hawaiian	0.278	0.099	2.82†
Filipino	0.212	0.101	2.10*
Oriental	-0.123	0.094	-1.31
Other	-0.024	0.135	-0.18
Resident island	-0.328	0.088	-3.72††
Pregnancy order	-0.033	0.024	-1.41
Current marital status	-0.035	0.103	-0.34
Woman's education	-0.032	0.016	-2.04*
History of induced abortion	-0.017	0.174	-0.10

Relative risk = $e^{-0.017}$ = 0.98.

* Significant at 0.05 level.

† Significant at 0.01 level.

†† Significant at 0.001 level.

TABLE 88 Distribution of matched pairs, by congenital malformations

	Control group		
Abortion group	Malformations	No malformations	Total
Malformations	3	77	80
No malformations	68	3,268	3,336
Total	71	3,345	3,416

Frequency of malformations for abortion group = 0.0234.

Frequency of malformations for control group = 0.0208.

Relative risk = 1.13.

TABLE 89 Estimated coefficients of multivariate logistic function and significance test for congenital malformations: hospital data

Variable	Coefficient	Standard error	z
Constant	−15.403		
Year of outcome	0.152	0.061	2.50*
Woman's age	−0.011	0.021	−0.50
Race			
Hawaiian or part-Hawaiian	0.335	0.239	1.40
Filipino	0.549	0.266	2.07*
Oriental	0.288	0.231	1.24
Other	0.318	0.371	0.86
Resident island	0.224	0.225	1.00
Pregnancy order	0.027	0.061	0.45
Current marital status	−0.267	0.237	−1.13
History of induced abortion	0.113	0.173	0.65

Relative risk = $e^{0.113}$ = 1.12.

* Significant at 0.05 level.

TABLE 90 Matched-pair comparisons of congenital malformations (CM) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
CM	2	1	4	11	10	4
No CM	38	39	329	322	524	530
Total	40	40	333	333	534	534
p	0.0500	0.0250	0.0120	0.0330	0.0187	0.0075
X^2_1	0		2.46		1.81	
RR	2.00		0.36		2.50	

(Table 90). The result was consistent with the foregoing observations, however. The small sample size of hospital data precluded separate treatment of specific types of malformations.

Table 91 summarizes the adjusted relative risk of factors associated with previous induced abortion. None of the factors investigated could be shown to be significantly related to the risk of congenital malformations in subsequent pregnancies of mothers with a history of induced abortion.

In view of our general finding of a lack of association between prior induced abortion and complications during subsequent pregnancies

TABLE 91 Adjusted relative risks of congenital malformations associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
<20	1.25	0.84
20–24	1.03	0.001
25–29	1.11	0.04
>29	0.68	0.17
Number of IAs		
1	1.05	1.05
>1	1.44	1.11
Gestation weeks at last IA		
<9	0.74	1.22
9–12	1.29	1.40
>12	1.51	1.77
Procedure		
D&C	1.11	0.03
Suction	0.90	0.11
Saline	1.69	1.81
D&C + suction	1.15	0.25
Use of laminaria		
No	1.02	0.002
Yes	1.32	1.12
Abortion complications		
No	1.04	0.03
Yes	1.80	2.35

and deliveries, it is not surprising that no relationship could be found between abortion and the risk of congenital malformations in babies conceived later. Thus our conclusion is in agreement with recent studies done in the United States (Daling and Emanuel, 1977; Schoenbaum et al., 1980; Bracken and Holford, 1979) and Taiwan (Daling and Emanuel, 1975), in which confounding variables were reasonably well controlled. The only published report claiming malformations as an adverse effect of prior induced abortion was by Harlap and Davies (1975), who also reported many other adverse effects and whose sample may therefore represent an environment distinct from ours.

Postnatal death

For the purpose of this study, postnatal death was defined to include all deaths of single-born infants occurring within one year after reported birth. We took this as a measure of postnatal mortality in the hope that the measure accurately reflected long-term residual effects, if any, of induced abortion of previous pregnancies.

Table 92 shows the distribution of postnatal mortality rates for the study and control groups as grouped by maternal age and parity. No significant association emerged between the risk of postnatal mortality and induced abortion of previous pregnancies ($\chi^2_1 = 0.20$, $P = 0.65$), the relative risk being estimated at 0.92. This finding was further corroborated by logistic regression analysis incorporating other pertinent covariates (Table 93). The relative risk estimated from the model was 0.99 ($z = -0.08$, $P = 0.94$). Because of the probable biological irrelevance of parity to postnatal death, we did no further Mantel-Haenszel χ^2 on the data stratified by parity combinations.

Table 94 presents the distribution of mortality for the matched hospital data. The general mortality rate observed in these data was somewhat lower than that revealed by the vital records, but postnatal mortality was found again to be unrelated to prior induced abortion ($\chi^2_1 = 0.01$, $P = 0.92$), the estimated relative risk being 1.18. The death rates were 1.19 percent and 1.02 percent for the abortion and control groups, respectively. This finding was further supported by the logistic regression analysis (Table 95). Because of extremely small numbers of infant deaths, the result of the parity-matched comparisons was not very informative (Table 96).

Table 97 shows the adjusted relative risks and significance tests for the various factors associated with last induced abortion. Not surpris-

TABLE 92 Postnatal death (< one year) associated with subsequent pregnancies of abortion and control groups, by age and parity
(Parity 0 or 1+ for both groups)

	Abortion group				Control group			
Age group and parity	Death	No death	Total	Prop.	Death	No death	Total	Prop.
< 20								
0	5	383	388	0.0129	178	12,511	12,689	0.0140
1+	1	44	45	0.0222	63	1,805	1,868	0.0337
20–24								
0	11	888	899	0.0122	217	19,456	19,673	0.0110
1+	8	412	420	0.0190	220	10,269	10,489	0.0210
25–29								
0	8	634	642	0.0125	100	11,724	11,824	0.0085
1+	7	485	492	0.0142	225	13,123	13,348	0.0169
> 29								
0	2	161	163	0.0123	53	4,014	4,067	0.0130
1+	5	366	371	0.0135	200	11,347	11,547	0.0173
Total	47	3,373	3,420	0.0137	1,256	84,249	85,505	0.0147

$X^2_1 = 0.20$.
$P = 0.65$.
Relative risk = 0.92.

ingly, none of the factors studied was found to be a significant risk factor for postnatal death.

Our finding is consistent with recently published studies on the subject (Daling and Emanuel, 1975; Daling and Emanuel, 1977; Schoenbaum et al., 1980). One exception is again the study in Israel by Harlap and Davies (1975), who found a significant increase in the *neonatal* death rate among infants of women with a history of induced abortion. Since most of the other studies dealt with neonatal death (death occurring less than 28 days after birth), we also examined the incidence of neonatal death in our samples, using the linked vital records for this purpose. Tables 98 and 99 show the results of the

Mantel-Haenszel χ^2 analysis and the logistic regression analysis, respectively. The conclusion remains the same, demonstrating further consistency.

TABLE 93 Estimated coefficients of multivariate logistic function and significance test for postnatal death: all vital data

Variable	Coefficient	Standard error	z
Constant	−3.762		
Year of outcome	−0.020	0.013	−1.54
Woman's age	−0.002	0.007	−0.31
Race			
Hawaiian or part-Hawaiian	0.498	0.086	5.80††
Filipino	0.187	0.088	2.13*
Oriental	0.119	0.082	1.45
Other	−0.005	0.118	−0.04
Resident island	−0.052	0.077	−0.68
Pregnancy order	0.068	0.021	3.28†
Current marital status	−0.141	0.089	−1.58
Woman's education	−0.054	0.014	−3.93††
History of induced abortion	−0.012	0.151	−0.08

Relative risk = $e^{-0.012}$ = 0.99; * Significant at 0.05 level; † Significant at 0.01 level; †† Significant at 0.001 level.

TABLE 94 Distribution of matched pairs, by postnatal death status

	Control group		
Abortion group	Death	No death	Total
Death	1	33	34
No death	28	2,784	2,812
Total	29	2,817	2,846

Frequency of postnatal death for abortion group = 0.0119.

Frequency of postnatal death for control group = 0.0102.

Relative risk = 1.18.

TABLE 95 Estimated coefficients of multivariate logistic function and significance test for postnatal death: hospital data

Variable	Coefficient	Standard error	z
Constant	-2.921		
Year of outcome	-0.276	0.087	-3.17†
Woman's age	-0.040	0.031	-1.32
Race			
Hawaiian or part-Hawaiian	0.389	0.340	1.14
Filipino	0.773	0.380	2.03*
Oriental	0.501	0.330	1.52
Other	-0.087	0.528	-0.16
Resident island	-0.479	0.320	-1.50
Pregnancy order	0.160	0.088	1.82
Current marital status	0.588	0.347	1.69
History of induced abortion	-0.006	0.246	-0.02

Relative risk = $e^{-0.006}$ = 0.99.

* Significant at 0.05 level.

† Significant at 0.01 level.

TABLE 96 Matched-pair comparisons of postnatal death (PND) and relative risks (RR) for specific combinations of reproductive history

	Abortion	Control	Abortion	Control	Abortion	Control
	A1	S1	A1	P1	A1	P0
PND	1	0	2	3	6	2
No PND	34	35	293	292	435	439
Total	35	35	295	295	441	441
p	0.0286	0	0.0068	0.0102	0.0136	0.0045
X^2_1	0		0		1.14	
RR			0.67		3.00	

TABLE 97 Adjusted relative risks of postnatal death associated with factors of previous induced abortion (IA)

Factors	Relative risk	X^2_1
Age at first IA		
< 20	0.75	0.40
20–24	1.02	0.01
25–29	1.05	0.01
> 29	1.21	~0
Number of IAs		
1	0.93	0.02
> 1	1.03	0.03
Gestation weeks at last IA		
< 9	0.52	2.18
9–12	1.14	0.09
> 12	1.49	0.67
Procedure		
D&C	1.00	0.04
Suction	0.82	0.21
Saline	1.88	1.25
D&C + suction	0.85	0.07
Use of laminaria		
No	0.86	0.18
Yes	1.20	0.11
Abortion complications		
No	0.97	~0
Yes	0.65	0.07

TABLE 98 Neonatal death (< 28 days) associated with subsequent pregnancies of abortion and control groups, by age and parity
(Parity 0 or 1+ for both groups)

	Abortion group				Control group			
Age group and parity	Death	No death	Total	Prop.	Death	No death	Total	Prop.
< 20								
0	5	383	388	0.0129	135	12,554	12,689	0.0106
1+	1	44	45	0.0222	42	1,826	1,868	0.0225
20–24								
0	5	894	899	0.0056	178	19,495	19,673	0.0090
1+	5	415	420	0.0119	152	10,337	10,489	0.0145
25–29								
0	7	635	642	0.0109	78	11,746	11,824	0.0066
1+	6	486	492	0.0122	160	13,188	13,348	0.0120
> 29								
0	1	162	163	0.0061	48	4,019	4,067	0.0118
1+	5	366	371	0.0135	150	11,397	11,547	0.0130
Total	35	3,385	3,420	0.0102	943	84,562	85,505	0.0110

$\chi^2_1 = 0.15$.

$P = 0.70$.

Relative risk = 0.92.

TABLE 99 Estimated coefficients of multivariate logistic function and significance test for neonatal deaths: all vital data

Variable	Coefficient	Standard error	z
Constant	-3.986		
Year of outcome	-0.060	0.015	-3.98*
Woman's age	0.011	0.008	1.43
Race			
Hawaiian or part-Hawaiian	0.371	0.099	3.73*
Filipino	0.172	0.102	1.69
Oriental	0.103	0.095	1.08
Other	0.070	0.136	0.51
Resident island	-0.090	0.089	-1.01
Pregnancy order	0.006	0.024	0.27
Current marital status	-0.062	0.103	-0.60
Woman's education	-0.057	0.016	-3.61*
History of induced abortion	-0.001	0.175	-0.01

Relative risk = $e^{-0.001}$ = 1.00.

* Significant at 0.001 level.

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